UNITED STATES DEPARTMENT OF THE INTERIOR
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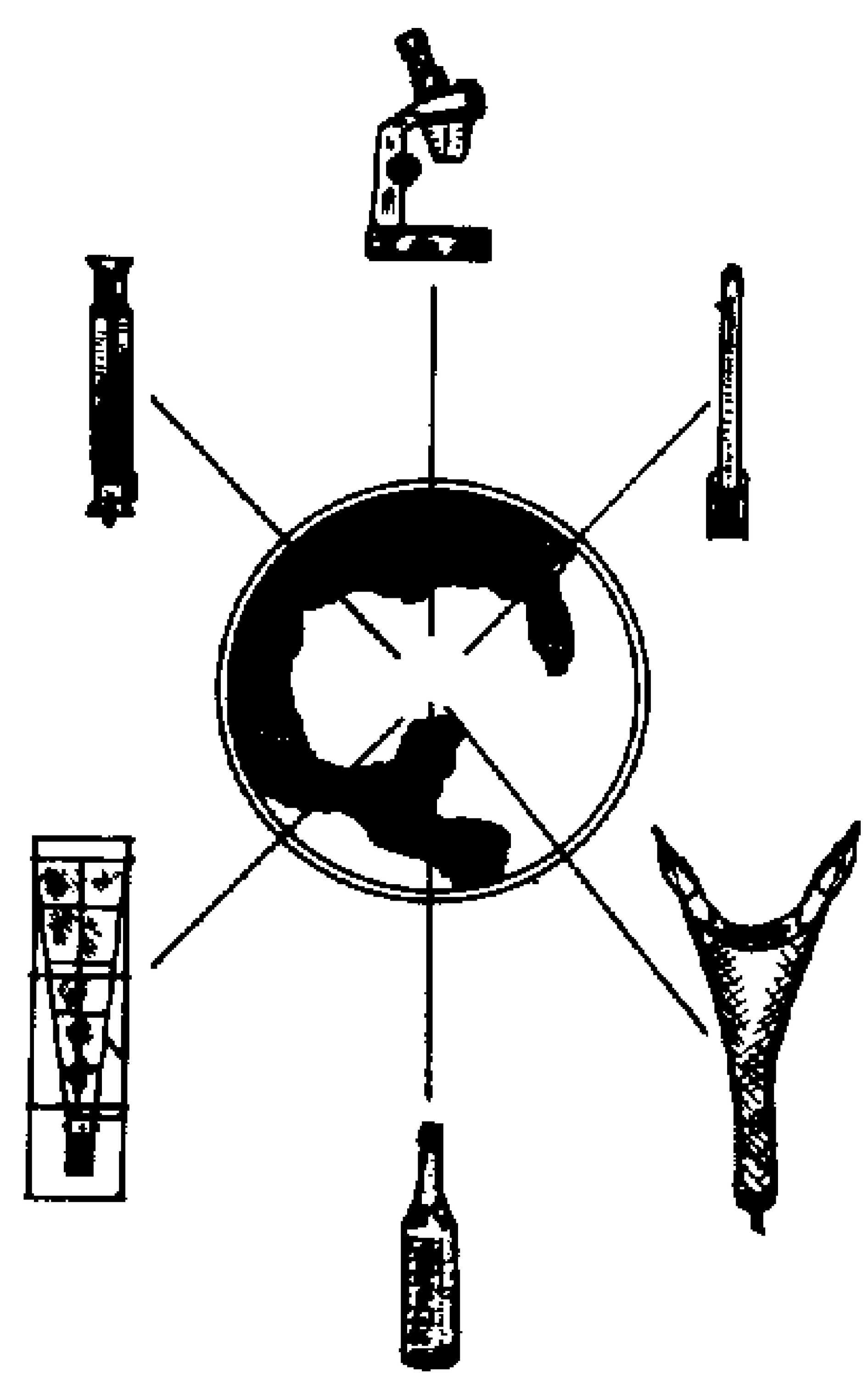
Stanley A. Cain, *Assistant Secretary for Fish and Wildlife and Parks*
FISH AND WILDLIFE SERVICE, Clarence F. Pautzke, *Commissioner*
BUREAU OF COMMERCIAL FISHERIES, Donald L. McKernan, *Director*

Annual Report of the Bureau of Commercial Fisheries Biological Laboratory, Galveston, Texas

Fiscal Year 1965

Milton J. Lindner, Director
Joseph H. Kutkuhn, Assistant Director



Contribution No. 208, Bureau of Commercial Fisheries
Biological Laboratory, Galveston, Tex.

Circular 246

Washington, D.C.
June 1966

The Bureau of Commercial Fisheries Biological Laboratory, Galveston, Tex., and its field stations conduct fishery research in the Gulf of Mexico as part of the work of the Bureau's Gulf and South Atlantic Region (Region 2), which comprises the eight coastal States from North Carolina to Texas.

Office of the Regional Director, Seton H. Thompson, is in the Don Ce-Sar Federal Center (P.O. Box 6245), St. Petersburg Beach, Fla.

Biological Research:

Biological Laboratory, Beaufort, N.C.
Radiobiological Laboratory, Beaufort, N.C.
Biological Laboratory, Brunswick, Ga.
Biological Laboratory, Galveston, Tex.
Biological Laboratory, Gulf Breeze, Fla.
Biological Laboratory, Washington, D.C. (Miami, Fla., late 1965)
Biological Field Station, Miami, Fla.
Biological Field Station, Pascagoula, Miss. (terminated 1/65)
Biological Field Station, St. Petersburg Beach, Fla.

Industrial Research:

Exploratory Fishing and Gear Research Base, Pascagoula, Miss., auxiliary bases at Panama City, Fla., and St. Simons Island, Ga.
Marketing--Marketing Offices in Atlanta, Ga.; Dallas, Tex.; Pascagoula, Miss.; and St. Petersburg Beach, Fla.
Technology--Technological Laboratory, Pascagoula, Miss.

Resource Development:

Loans and Grants Office, St. Petersburg Beach, Fla.
Statistical Center and Market News Office, New Orleans, La.

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Annual Report of the Bureau of Commercial Fisheries Biological Laboratory Galveston, Texas, Fiscal Year 1965

ABSTRACT

The program of the laboratory in Galveston involves fisheries biology and oceanography research of the commercial fishery resources in the Gulf of Mexico. Particular emphasis is on shrimp research.

REPORT OF THE DIRECTOR

GENERAL

The programs of the Laboratory were reorganized during the year. The Industrial Bottomfish Program was phased out, and two new projects--cultivation of shrimp in artificial ponds and ecologically associated organisms--were added to the Shrimp Biology Program. Also, arrangements were made to start a modest Gulf Oceanographic Program during fiscal year 1966. Four programs were operating at the close of the fiscal year: Shrimp Biology, Shrimp Dynamics, Experimental Biology, and Estuarine Programs.

Research in these programs, though diverse, is intermeshed with the emphasis on shrimp. The leaders of each program have summarized their research so that a review of their work is not given in this section. These summaries are at the beginning of each program discussion.

LABORATORY FACILITIES

The exteriors of the Laboratory buildings continue to deteriorate and each year become more unsightly; however, we have been able to improve the grounds and building interiors. Several offices and laboratories were redecorated, and acoustical ceilings installed. Special aquarium stands were constructed in the Experimental Biology Section and the Museum, and new display cabinets were placed in the Museum. Two 1/8-acre ponds were completed near the East Lagoon laboratory. Fire escapes serving the two main laboratory buildings were modified and relocated to provide more efficient emergency exits. New exhaust devices, developed by one of the staff to eliminate formaldehyde fumes, were built for three of the laboratories.

SAFETY

Meetings of the Safety Committee were held monthly and were coordinated with safety education for the entire staff. The Committee continued its quarterly tour of the Laboratory to review safety and housekeeping practices. Each member of the Safety Committee evaluates all accident reports, which are then forwarded to the Regional Office.

National Safe Boating Week was observed with appropriate activities, including inspection of all life-saving equipment.

Fire Prevention Week (October 4-10) was formally observed through a meeting of all Laboratory personnel at which two movies were shown, and an inspector from the Galveston Fire Department spoke on fire safety. We also checked Laboratory facilities for fire hazards, and reviewed and updated the written procedures for action in the event of fire.

J. C. Jones, Fish and Wildlife Service Safety Officer (Washington, D.C.), reviewed our safety program. We established a Laboratory library of safety material.

The Laboratory Director urged all employees to take part in the nationwide driver's test which the National Safety Council sponsored in cooperation with the Columbia Broadcasting System on May 24, 1965.

PUBLIC RELATIONS

More than 1,000 students and their instructors and about 130 other visitors were given Laboratory tours, field trips, or both. The students were from 7 different universities the volume back up with fresh culture medium.

A new method of sterilizing algal culture tanks with ultraviolet light is being used routinely (Fig. 1). It is apparently an effective means of eliminating bacteria and algal contaminants from the tanks between uses.

The possibility of utilizing rotifers as a food or a food supplement with brine shrimp (*Artemia*) was tested for larval brown shrimp. Preliminary results indicate that mixed cultures (*Dunaliella*-rotifer-*Artemia*) produce the greatest gain in total length (tip of rostrum to tip of telson) over a 40-day period.

A search for a chemical method of distinguishing laboratory-reared shrimp has led to studies involving flat-sheet and disc electrophoresis. These studies have revealed distinct differences between protein patterns of laboratory-reared and wild brown postlarval shrimp. Analyses have been based on individual specimens ranging in total length from 4.5 to 12 mm and on composite samples of up to several hundred specimens of the same size. As far as we have been able to determine, the patterns characterizing the two sources of shrimp are consistent and are not affected by the animal's diet.

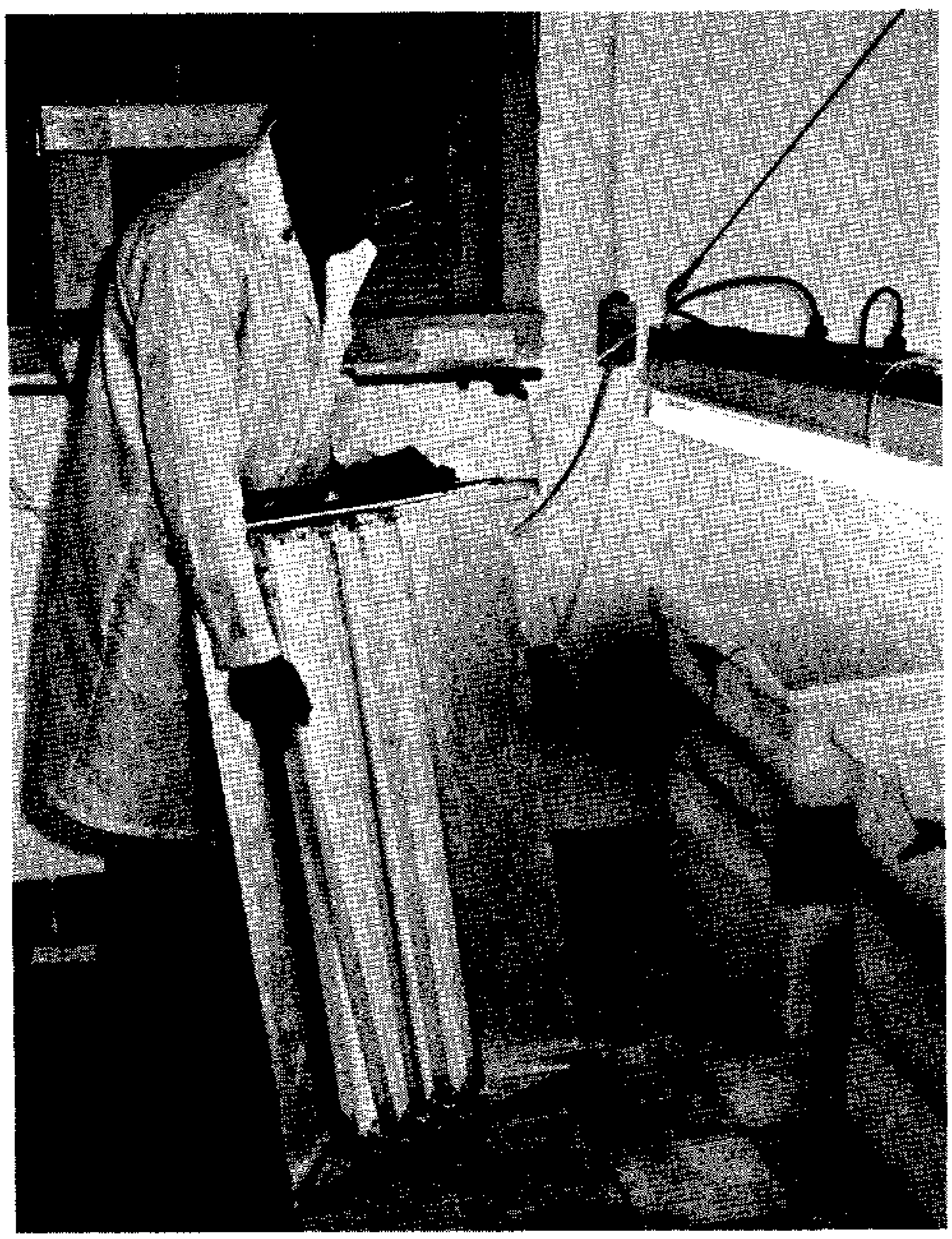

Figure 1. — Ultraviolet tank sterilizer which is placed on top of empty tanks when in use.

FOOD AND EXPERIMENTAL ENVIRONMENTS

A goal implicit in the artificial propagation and culture of any organism is the production of a standard high quality animal. Our recent goal has been to define the quality of the animals presently produced by our hatchery facilities, and to determine the effects on this standard of various modifications in the diet of both larval and postlarval brown shrimp.

Of primary interest was the testing of artificial salt solutions as a defined medium for use in our future experiments. To date, only one artificial salt made up in distilled water has been tested. No organic compounds were added to the water except in the food provided. Laboratory-hatched brown shrimp postlarvae were used as experimental animals. Postlarvae in the artificial salt solution grew slower than did animals in water from our seawater system. Furthermore, animals in the artificial medium showed increased rates of cannibalism, general sluggishness, and certain gross pathological conditions not noted in the animals in the natural waters. Individuals frequently had difficulty in completing a molt, or if they did molt, their exoskeletons did not harden. We are, therefore, continuing studies to define a medium adequate for the growth of postlarval and juvenile penaeids.

Variations between groups of laboratory-spawned and hatched shrimp were notable in differences in survival between larval stages, in growth rates of postlarvae fed a standard diet of naupliar brine shrimp, and in response to selected environmental conditions. For example, two groups of postlarvae—one hatched in October and a second in December — responded differently to changes of salinity or temperature. Differences in growth are equally notable, both within aquaria groups and between groups. In Figure 2 examples are presented of the best average growth, typical growth, and the poorest average growth observed among hatchery shrimp fed a diet of *Skeletonema* during protozoeal stages, followed by naupliar *Artemia* during mysis and postlarval stages. Even in the curve of best growth, ranges at each point are large — 13-55 mm in the final observation.

Larvae were also fed diatoms which were frozen slowly, or freeze-dried alone or in the presence of the progress as well as direction of the Laboratory's many research activities.

MEETINGS ATTENDED

Gulf States Marine Fisheries Commission's Shrimp Research Committee, New Orleans, La., July (3)[2]

American Institute of Biological Sciences, Boulder, Colo., August (2)

American Society of Ichthyologists and Herpetologists, Morehead City, N.C., September (1)

American Fisheries Society, Atlantic City, N.J., September (4)

American Fisheries Society (Southeastern Division), Clearwater, Fla., October (1)

Gulf States Marine Fisheries Commission, Brownsville, Tex., October (3)

Gulf and Caribbean Fisheries Institute, Ocho Rios, Jamaica, November (1)

Ninth Annual Water For Texas Conference, College Station, Tex., November (1)

Texas Shrimp Association, Brownsville, Tex., January (2)

Laboratory Director's meeting, Fishery Oceanography Center, La Jolla, Calif., January (1)

Committee for the Scientific Exploration of the Atlantic Shelf (SEAS), Wash., D.C., February (1)

Gulf States Marine Fisheries Commission, Mobile, Ala., March (2)

Interagency Motor Equipment Management Conference, Dallas, Tex., March (1)

Seminar on Management of River Basins, University of Texas, Austin, Tex., April (1)

Safety Management Seminar, Wash., D.C., May (1)

Regional Staff Conference, St. Petersburg Beach, Fla., May (1)

Special Libraries Association Meeting, Philadelphia, Pa., June (1)

Ocean Science and Ocean Engineering Conference with Exhibit, Wash., D.C., June (1)

Shrimp Association of the Americas, Miami, Fla., June (1)

Texas Professional Photographers Association, Austin, Tex., June (1)

WORK CONFERENCES

Meetings with officials of the Bureau of Reclamation, Bureau of Sport Fisheries and Wildlife, and states to work out details of the Service's contribution to Reclamation's report on the Texas Basins Project, Wash., D.C., July, September, February, and June (1)[3]; Austin, Tex., August (2); Amarillo, Tex., September (1)

Meetings with representatives of the Bureau of Sport Fisheries and Wildlife and the Louisiana Wild Life and Fisheries Commission to discuss continuing research on the effects of the Mississippi River-Gulf Outlet Project, New Orleans, La., August (2); Vicksburg, Miss., January, March, and April (1)

Participation in Department's Biennial Conference of Librarians, Wash., D.C., September (1)

Regional Staff Conference, St. Petersburg Beach, Fla., October (1)

Bureau-sponsored "red-tide" symposium, St. Petersburg Beach, Fla., October (3)

Meeting of U.S. Fish and Wildlife Work Group to determine water needs in the Sabine River Basin, April (1)

Conference in St. Petersburg Regional Office on contract research, May (2)

[2] [3] See footnote 1 on page 2.

PUBLICATIONS

Diener, Richard A.

1965a. Texas estuaries and water resource development projects. Proc. 9th Annu. Conf. Water Tex., Tex. A&M Univ., 25-31.

1965b. The occurrence of tadpoles of the green treefrog, *Hyla cinerea cinerea* (Schneider), in *Trinity Bay, Texas*. Brit. J. Herpet. 3(8):198-199.

Klima, Edward F.

1965. Evaluation of biological stains, inks, and fluorescent pigments as marks for shrimp. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 511, 8 p.

Marvin, Kenneth T., and Raphael R. Proctor, Jr.

1965. Stabilizing the ammonia-nitrogen content of estuarine and coastal waters by freezing. Limnol. Oceanogr. 10(2): 288-290.

Roithmayr, Charles M.

1965. Review of industrial bottomfish fishery in northern Gulf of Mexico, 1959-62. Com. Fish. Rev. 27(1):1-6.

MANUSCRIPTS IN PRESS

Aldrich, David V.

Observations on the ecology and life cycle of *Prochristianella penaei* Kruse (Cestoda: Trypanorhyncha). J. Parasitol. (19 MS. p., 4 figs.).

Cook, Harry L., and M. Alice Murphy.

Early developmental stages of the rock shrimp, *Sicyonia brevirostris Stimpson*, reared in the laboratory. Tulane Stud. Zool. (29 MS. p., 14 figs.).

Costello, T. J., and Donald M. Allen.

Migrations and geographic distribution of pink shrimp, *Panaeus duorarum*, of the Tortugas and Sanibel grounds, Florida. U.S. Fish Wildl. Serv., Fish. Bull. (23 MS. p., 7 figs.).

Marvin, K. T., and R. R. Proctor.
Comparison of two methods of N-ethyl-carbazole carbohydrate analysis. U.S. Fish Wildl. Serv., Fish. Bull. (6 MS. p., 1 fig.).

Mock, Cornelius R.
Range extension of the sipunculoidean annelid Phascolion strombi (Montagu) in the Gulf of Mexico. Tex. J. Sci. (3 MS. p.).

Parker, Jack C.
An annotated checklist of the fishes of Galveston Bay System, Texas. Publ. Instit. Mar. Sci. (46 MS. p., 1 fig.).

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Biological Laboratory, Galveston, Tex., fishery research for the year ending June 30, 1964. U.S. Fish Wildl. Serv., Circ. (109 MS. p.).

Zein-Eldin, Zoula P., and David V. Aldrich.
Growth and survival of postlarval Penaeus aztecus under controlled conditions of temperature and salinity. Biol. Bull. (Woods Hole) (35 MS. p., 6 figs.).

Zein-Eldin, Zoula P., and Edward F. Klima.
Effects of an injected biological stain on oxygen uptake by shrimp. Trans. Amer. Fish. Soc. (7 MS. p., 1 fig.).

MANUSCRIPTS SUBMITTED

Chapman, Charles R.
The Texas Basins Project. Trans. Amer. Fish. Soc. (20 MS. p., 6 figs.).

Kutkuhn, Joseph H.
The role of estuaries in the development and perpetuation of commercial shrimp resources. Trans. Amer. Fish. Soc. (72 MS. p., 2 figs.).

Mock, Cornelius R.
A new locality record for the lancelet, Branchiostoma caribaeum Sundevall, on the Texas coast. Copeia (2 MS. p.).

Roithmayr, Charles M.
The industrial bottomfish fishery of the northern Gulf of Mexico, 1959-63. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. (46 MS. p., 8 figs.).

STAFF

Milton J. Lindner, Laboratory Director
Joseph H. Kutkuhn, Assistant Laboratory Director [4]

Biological Laboratory at Galveston, Tex.
Field Stations at Miami, Fla., and Pascagoula, Miss. [5]

Shrimp Biology Program

Robert F. Temple	Program Leader (appointed 3/65)	Galveston
David L. Harrington	Biologist	Do.
Harry L. Cook	Biologist	Do.
Harold A. Brusher	Biologist	Do.
Clarence C. Fischer	Biologist	Do.
Donald Moore	Biologist	Do.
Ray S. Wheeler	Biologist	Do.
John B. Hervey	Biologist	Do.
Thomas J. Costello, Jr.	Head, Field Station	Miami
Donald M. Allen	Biologist	Do.
James H. Hudson	Biologist (transferred to Miami 10/64)	Key West
Nellie P. Benson	Clerk-Stenographer (WAE)	Miami
John L. Ledford	Aid (temporary)	Do.
Maud A. Murphy	Technician	Galveston
Maria E. Montemayor	Aid	Do.
Charles S. Law	Aid	Do.
Virginia L. Longley	Aid (temporary)	Do.
John L. Bethscheider	Summer Trainee	Do.
Douglas M. McIntyre	Summer Aid	Do.
J. Bruce Kimsey	Program Leader (transferred 2/65)	Do.
William C. Renfro	Biologist (resigned 8/64)	Do.
Imogene A. Sanderson	Technician (resigned 7/64)	Do.
Ann D. Barber	Aid (resigned 2/65)	Do.
Don E. Kozacek	Summer Aid (resigned 8/64)	Do.

[4] Transferred 6/65.
[5] Field Station activities at Pascagoula, Miss., discontinued 1/65.

Shrimp Dynamics Program

Richard J. Berry	Program Leader	Galveston
Kenneth N. Baxter	Biologist	Do.
Joseph A. Benigno	Biologist (educational leave 9/64-6/65)	Do.
Charles E. Knight	Biologist	Do.
James P. Clugston	Biologist	Do.
Charles J. Guice	Biologist	Do.
Thomas W. Turnipseed	Biologist	Morgan City
James M. Lyon	Biologist	Aransas Pass
Robert C. Benton	Biologist (transferred to Key West 12/64)	Freeport
Frank Marullo	Aid	Galveston
Clark T. Fontaine	Technician	Do.
Marcel J. Duronslet	Technician	Do.
Dennis A. Emiliani	Aid (temporary)	Do.
Carlton H. Furr, Jr.	Fishery Reporting Specialist (began 1-year leave of absence 2/65)	Do.
Joe E. Eberle	Summer Trainee	Do.
Geoffrey A. Matthews	Summer Aid	Do.
Carl R. Sparks, Jr.	Summer Aid	Do.
Edward F. Klima	Biologist (transferred 1/65)	Do.
Ignacio R. Bode	Aid (terminated 4/65)	Key West
Ronald L. Campbell	Aid (terminated 4/65)	Marathon
Guerry P. Hersey	Aid (terminated 5/65)	Key West
Walter I. Peden	Aid (terminated 4/65)	Do.
Robert M. Blade	Summer Aid (resigned 9/64)	Galveston
Randall W. Bland	Summer Aid (resigned 8/64)	Do.
Edward S. Halpert	Summer Aid (resigned 8/64)	Do.

Experimental Biology Program

David V. Aldrich	Program Leader	Galveston
Zoula P. Zein-Eldin	Research Chemist	Do.
George W. Griffith	Biologist	Do.
Ausbon Brown, Jr.	Technician	Do.
James T. Whitman	Aid (temporary)	Do.
Vernon L. Rainey	Summer Aid	Do.
Carl E. Wood	Summer Aid	Do.
Linda A. Edwards	Aid (resigned 6/65)	Do.
James A. Supej	Aid (resigned 3/65)	Do.

Estuarine Program

Charles R. Chapman	Program Leader	Galveston
Jack C. Parker	Biologist	Do.
Richard A. Diener	Biologist	Do.
Robert D. Ringo	Biologist	Do.
Edward J. Pullen	Biologist	Do.
Cornelius R. Mock	Biologist	Do.
William Laming	Fishery Methods and Equipment Specialist	Do.
Genevieve B. Adams	Statistical Clerk	Do.
Gilbert Zamora, Jr.	Technician	Do.
Jean O. Allen	Summer Aid	Do.
Wayne E. Sanderson	Summer Trainee	Do.
William T. Ladnier	Aid (resigned 8/64)	Do.

Industrial Bottomfish Fishery Program [6]

Joseph H. Kutkuhn	Program Leader (transferred 6/65)	Galveston
Charles M. Roithmayr	Biologist (transferred 1/65)	Pascagoula
Leslie D. Osborne, Jr.	Aid (transferred 1/65)	Do.

[6] Program terminated 1/65.

Chemistry and Sea-Water Laboratories

Kenneth T. Marvin	Supervisory Chemist	Galveston
Raphael R. Proctor, Jr.	Chemist	Do.
Larence M. Lansford	Technician	Do.
James Wallett	Technician	Do.
Albert L. Kudelka	Summer Trainee	Do.

Library

Stella Breedlove	Librarian	Galveston
Shirley J. Chatmon	Summer Trainee	Do.

Technical Services

Ruth W. Yanch	Secretary	Galveston
Petronila C. Prado	Clerk-Stenographer	Do.
Elizabeth C. Kilian	Clerk-Stenographer	Do.
Laura M. Hermann	Museum Technician (Nat. Sci.)	Do.
Daniel Patlan	Office Draftsman	Do.
Margie L. Watson	Clerk-Stenographer (resigned 4/65)	Do.

Administration and Maintenance

Raymond H. Niblock	Administrative Officer	Galveston
Glo S. Baxter	Administrative Clerk	Do.
Corinna L. Denbo	Purchasing Agent	Do.
Alvin M. Reynolds	Supply Clerk	Do.
Peter M. Villarreal	Maintenance Foreman	Do.
Tidas C. Alcorn	Maintenance man	Do.
Robert L. McMahon	Maintenance man	Do.
William D. Muir	Summer Trainee	Do.

SHRIMP BIOLOGY PROGRAM

Research of the Shrimp Biology Program is designed to provide an understanding of the life history of commercially important shrimp. Sound management practices can then be established to ensure full utilization of this valuable resource.

During fiscal year 1965, research cruises were made in the waters over the northwestern Continental Shelf of the Gulf of Mexico between the Mississippi River and Brownsville, Tex. Each month, biological and hydrological measurements were obtained at 41 stations, ranging in depths from 4 to 60 fath. At each station, sampling procedure entailed making a 20-min. plankton haul with a Gulf-V plankton sampler and obtaining temperature and salinity measurements at various depths. One-hr. tows with a 45-ft. shrimp trawl were made at selected stations, and drift bottles were released during several months. We also made shorter cruises to obtain gravid shrimp for experimental rearing of the larvae and to measure water currents (fig. 1).

One of our major problems has been to identify larval shrimp in plankton samples; therefore, we have spent considerable effort in attempting to rear shrimp of known parentage and accurately describing each stage. During this past year, we made a major advancement when brown shrimp (Penaeus aztecus), pink shrimp (P. duorarum), and Trachypeneus similis were successfully reared to postlarvae. Further advancement was made toward developing a mass culture technique for shrimp. Two species of penaeid shrimp were reared in mass culture, to which, in addition to food, the only additive was disodium salt of the metal chelator E.D.T.A. (ethylenediaminetetraacetic).

In conjunction with the study of plankton-stage abundance and distribution, we continued investigating the possibility that postlarvae of the Penaeus species concentrate on the bottom before they move into nursery areas. By modifying a Clarke-Bumpus sampler [7] and mounting it on a sled, we were able to collect plankton samples within 5 to 6 in. of the bottom. Our search for postlarval Penaeus, however, was unsuccessful. Analysis of regularly collected plankton samples continued, and 2 yr. of comparable data are now available.

[7] Trade names are used in this report for identification only. Their appearance does not imply endorsement by the Bureau of Commercial Fisheries.

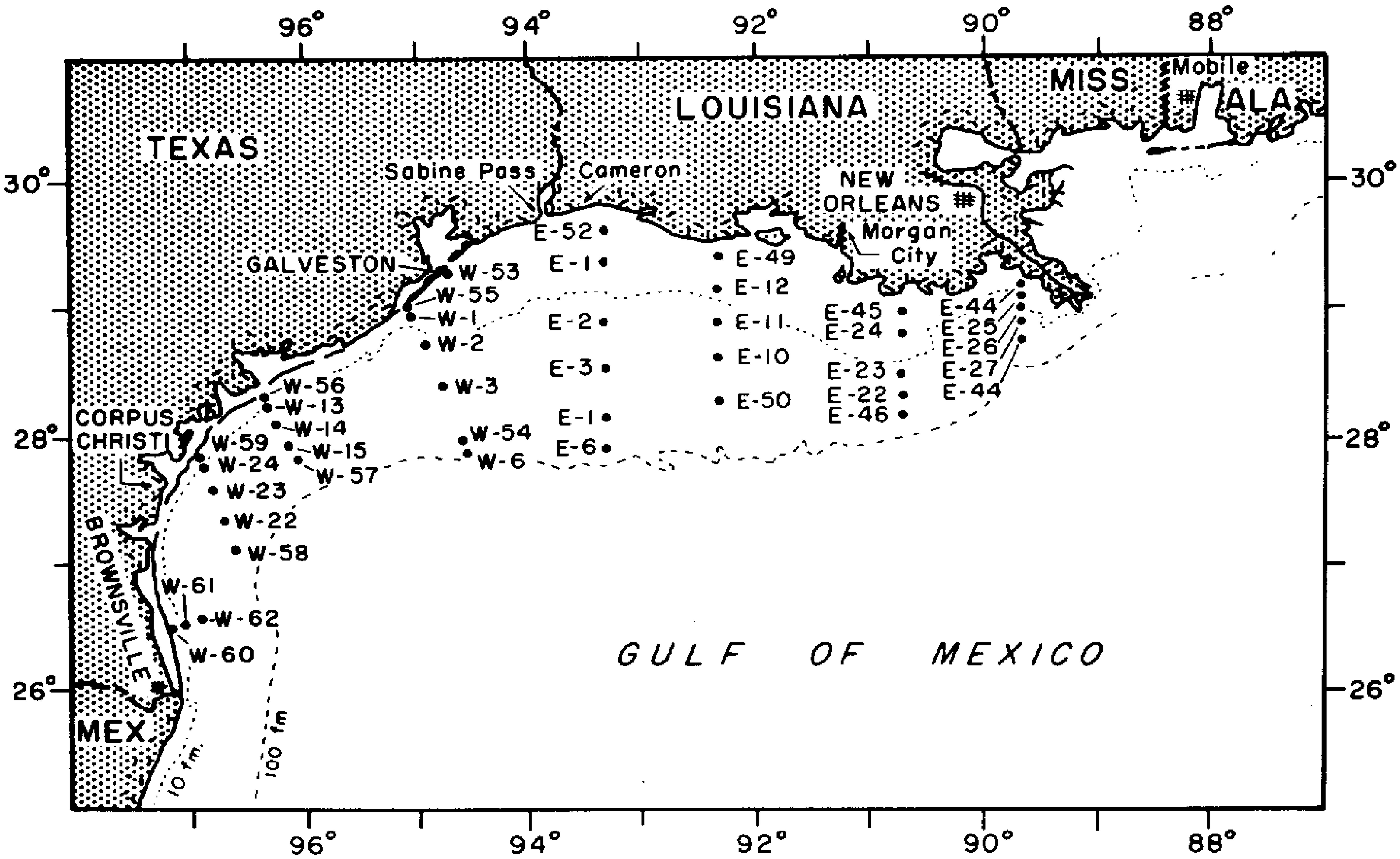

Figure 1.--Offshore station pattern for operations of the Shrimp Biology Program.

Monthly isohaline and isothermal charts were drawn from the temperature and salinity data collected concurrently with biological samples. In addition, we made several 24-hr. current studies in an effort to evaluate the role of water currents in the inshore transport of larval shrimp.

The examination of fish samples collected for the Industrial Fish Program has been completed, providing 3 yr. of data. These data are being analyzed to determine seasonal distribution and abundance of many fish species; particular emphasis is directed toward investigating the possibility of co-occurrence of fish and shrimp populations.

A new project, "Cultivation of Shrimp in Artificial Ponds," began in December 1964. Although success has varied in our first attempts to rear shrimp in manmade ponds, the resulting information should enable us to assess the factors that affect growth and survival of shrimp reared under seminatural conditions.

At our Miami Field Station, personnel have been engaged in another relatively new phase of research designed to study the ecology of juvenile pink shrimp in Florida Bay. Considerable effort was spent in developing a suction dredge that would quantitatively sample shrimp and other fauna. Systematic sampling is now in progress.

Robert F. Temple, Program Leader

OCEANOGRAPHIC OBSERVATIONS ON THE CONTINENTAL SHELF OF THE NORTHWESTERN GULF OF MEXICO

With the continuation of this project in fiscal year 1965, physical oceanographic measurements and meteorological observations were made monthly at 41 stations over the Continental Shelf of the northwestern Gulf of Mexico (fig. 1). About 700 bathythermograph slides and 2,000 water samples have been processed during the year, and the resulting data analyzed and filed.

Surface Salinities

The distribution of surface salinities varied slightly during January to March 1964. Isohalines paralleled the Louisiana and Texas coasts and ranged from 30.0 p.p.t. (parts per thousand) along the shoreline to 36.0 p.p.t. out to the 10-fath. contour. Beyond this point, salinities were close to 36.5 p.p.t. Deviations from this general distribution were evident in February when two intrusions of water in excess of 36.8 p.p.t. extended onto the Continental Shelf areas of Texas and Louisiana. Remnants of these intrusions were represented in March by two isolated, high-salinity water masses in about the same areas as the February intrusions.

Surface salinities changed markedly with increased river discharge in April and June.

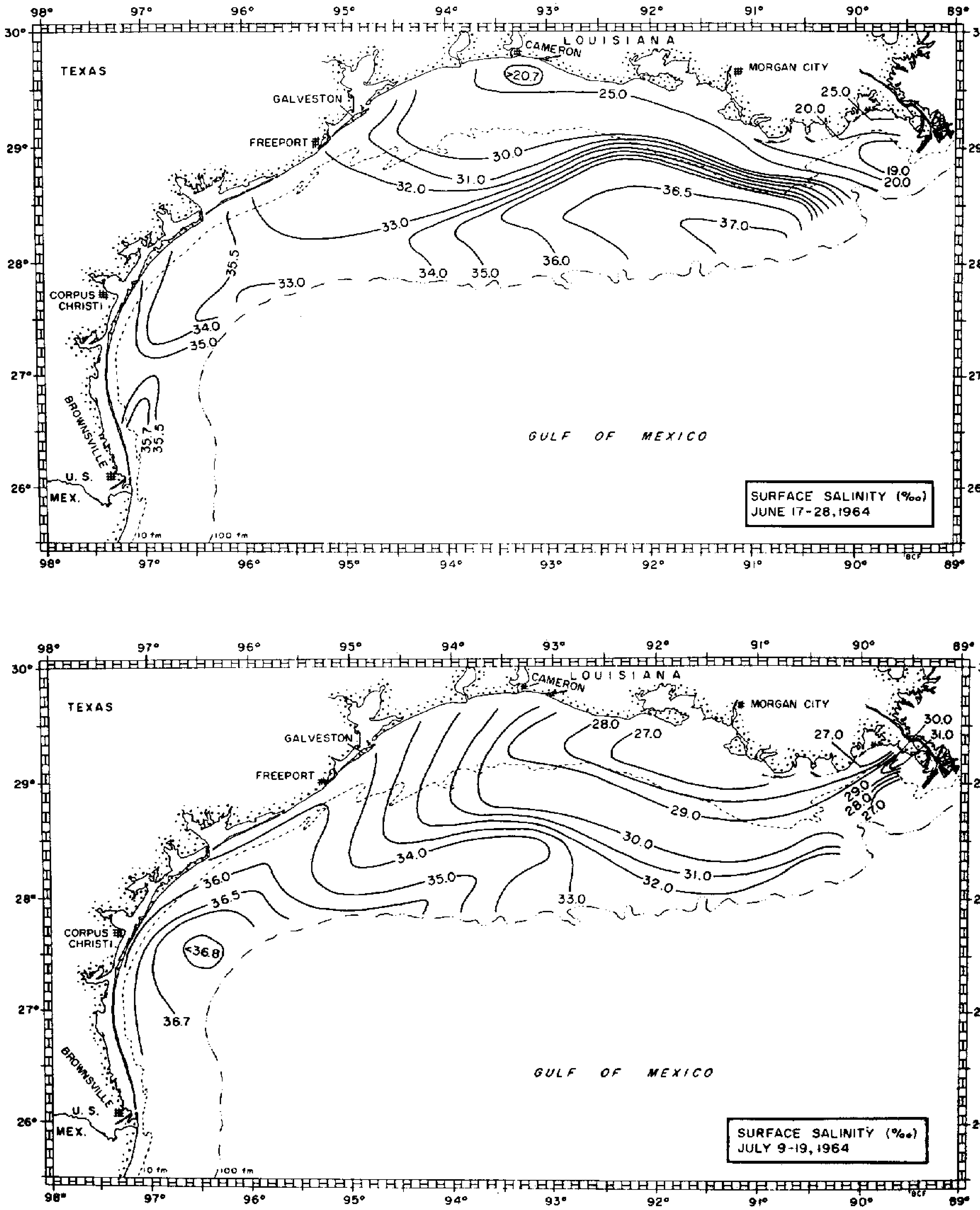

Figure 2.--The distribution of surface salinity on the Continental Shelf of the northwestern Gulf of Mexico from June 17 to 28 and July 9 to 19, 1964.

Salinities as low as 14.0 p.p.t. were observed along the Louisiana coast. These low-salinity waters apparently flowed westward and extended over the Continental Shelf along the Texas coast where salinities were as low as 32.0 p.p.t. 60 miles offshore (fig. 2). This freshening of coastal waters, coupled with an extensive shoreward intrusion of high-salinity waters, resulted in a steep salinity gradient along the Louisiana coast.

The distribution of salinities in July and August suggested an apparent shift in surface currents. The intrusion of high-salinity waters observed earlier along the Louisiana coast had shifted and was now evident along the central Texas coast.

The effects of decreased river discharge became apparent in the salinity distribution from September to December. Conditions similar to those from January to March prevailed generally throughout the study area. Isohalines paralleled the coast and ranged from 30.0 p.p.t. inshore to 36.5 p.p.t. offshore. The only offshore extension of moderately low-salinity water (34.0 p.p.t.) was in September, south of Morgan City, La., and extended offshore beyond the limit of the study area.

Surface Temperatures

Seasonal warming and cooling of surface waters in 1964 were closely related to seasonal changes in prevailing air temperatures. Yearly temperature ranges, however, decreased with increase in distance from the coast. Shoreward of the $7\frac{1}{2}$-fath. contour, surface water temperatures varied over a range of 21.0° C. (37.8° F.), but they varied only 14.0° C. (25.3° F.) over the 60 fath. contour. Lowest temperatures (10.0° C. or 50.0° F. inshore and 19.0° C. or 66.2° F. offshore) occurred in January off the Louisiana coast; highest temperatures (31.0° C. or 87.8° F.), also along the Louisiana coast, were recorded in August.

Bottom Temperatures

Warming and cooling at the bottom are not the steady progressions seen at the surface. Bottom values reach their maximum at the time of fall turnover--during late summer in the shallower waters and gradually later offshore where conditions are uniform in December or January. Bottom temperatures shoreward of the $7\frac{1}{2}$-fath. stations fluctuated over a range of 21.0° C. (37.8° F.), but varied only 3.0° C. (5.4° F.) at the outermost station (60 fath.). The highest bottom values (30.0° C. or 86.0° F.) were inshore in August and offshore (19.0° C. or 66.2° F.) between October and January. During September and December, when offshore bottom temperatures were still increasing, coastal waters were cooling; consequently, cooler temperatures prevailed inside and outside a zone of warmer waters located between the 15- and 25-fath. contours.

Studies of Currents

Plans for a more intensive study of water currents and their role in larval shrimp transport from offshore spawning grounds to estuarine systems have been outlined and preliminary phases completed. In May 1965, a 24-hr. anchor station was maintained through use of a transistorized savonius-type current meter and several Carruthers gelatin bottles to measure currents. The aims of this work were: (1) to develop a system and technique for making gelatin-bottle casts, (2) to compare the results from each type of instrument, and (3) to measure existing water currents on spawning grounds of white shrimp.

A position off the Louisiana coast in the center of fairly extensive white shrimp fishing was selected for current studies. Hourly observations, with both instruments, were made at depths of 10 and 23 ft. Additional observations were made 1 ft. above bottom with the gelatin bottle and 10 ft. above the bottom with the Savonius current meter. An efficient system was developed for making gelatin-bottle casts, and results showed similar readings from the different instruments (fig. 3). At depths of 10 and 23 ft., the difference between instruments in resultant current directions did not exceed 7°, and resultant velocities varied no more

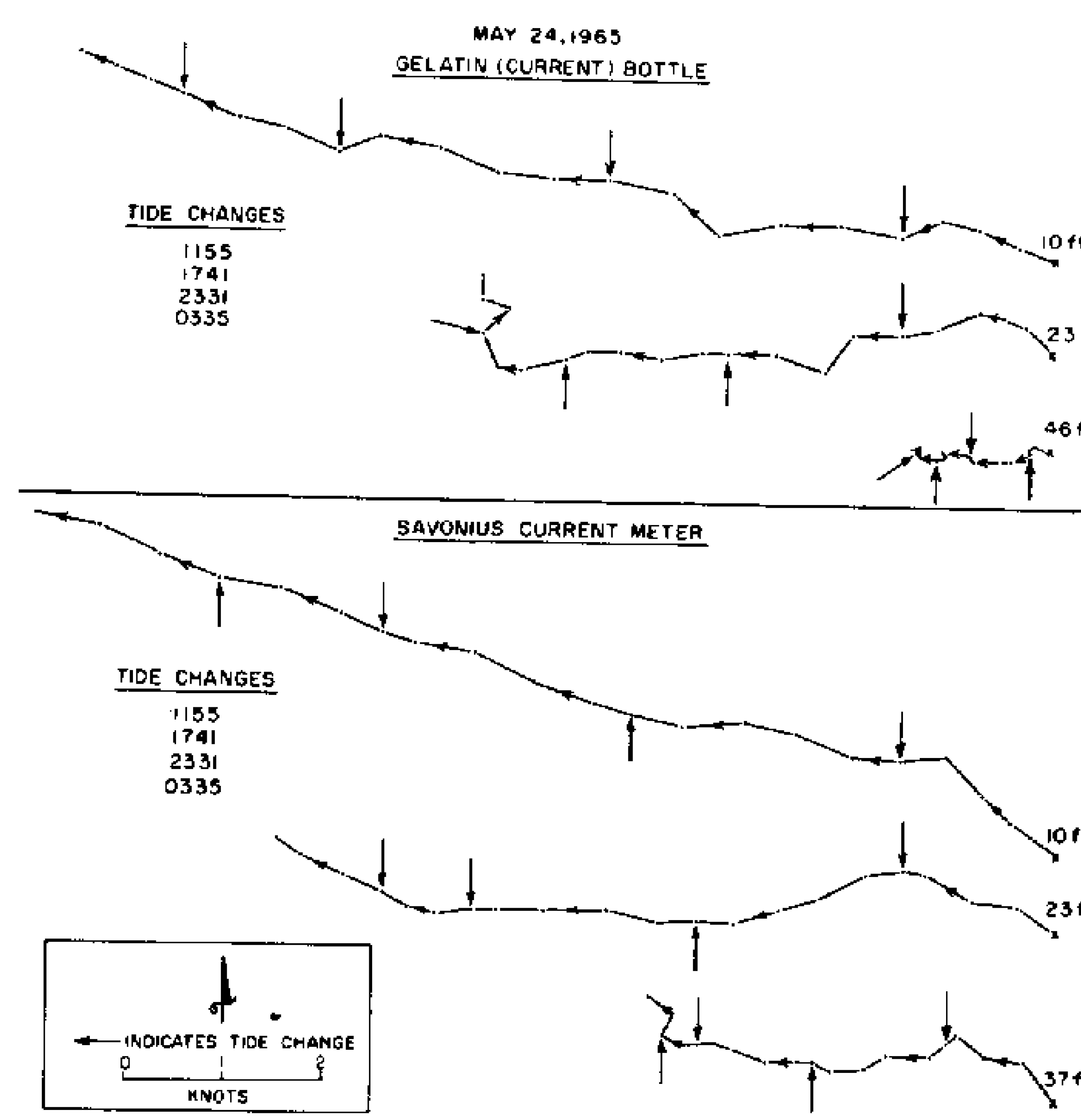

Figure 3.--Hourly current measurements obtained simultaneously with the galatin bottle and the savonius current meter, May 24, 1965.

than 0.17 kn. Progressive vector analysis revealed a westerly current at all depths; the velocity decreased as depth increased. The average resultant current at 10 ft. was flowing 285° at 0.85 kn., whereas the current at 23 ft. averaged 277° at 0.55 kn. Although direction and velocity differences between instruments were slightly greater within 10 ft. of the bottom, currents were also flowing westerly.

David L. Harrington, Project Leader

Distribution and Abundance of Shrimp Larvae

A thorough knowledge of the life history of the planktonic stages of shrimp is essential to understand and manage offshore shrimp populations. To attain this knowledge, we have, since 1962, been extensively sampling offshore in the northwestern Gulf of Mexico. We collected plankton samples monthly at predetermined stations along transects extending from $4\frac{1}{2}$ to 60 fath. At each station, a 20-min., "step-oblique" plankton tow is made with a Gulf-V plankton net. We sorted penaeid shrimp larvae and postlarvae from the samples. The resulting data, reported in number of organisms per 100 $m.^3$ (3,534 $ft.^3$) of water strained, provided information on seasonal and areal distribution and abundance of planktonic-stage penaeids. All samples collected through December 1963 have been examined, providing 2 yr. of comparable data for the survey area.

Catch Composition between 1962 and 1963

Six genera of planktonic-stage penaeids occurred in plankton samples from the survey area: the commercially important shrimp, *Penaeus* (white, brown, and pink shrimp), and the noncommercially important shrimp genera, *Trachypeneus*, *Xiphopeneus*, *Sicyonia*, *Solenocera*, and *Parapenaeus*. Catch data grouped for all genera indicated that planktonic stages were more abundant in 1963 than in 1962 (table 1). This difference was caused by a twofold increase in numbers of *Penaeus* species and "TX" species in the western portion (Galveston to Brownsville) of the study area. (Young shrimp of the genera *Trachypeneus* and *Xiphopeneus* are combined and designated "TX" in this report because it is impossible now to differentiate between them.)

Seasonal Distribution of Commercial Species, 1963

Spawning, as indicated by the scarcity of early stages (naupliar and protozoeal) in plankton samples, was low in January to March. During this period, planktonic-stage *Penaeus* species were present in most of the survey area except for an area southeast of Corpus Christi, Tex. Concentrations were greatest inside the 15-fath. contour and extended along the coast from central Texas to Louisiana. About 55 percent of the catch was postlarval shrimp. Postlarval brown shrimp were entering the bays during this time, and about 50 percent of the total postlarval catch was taken at $4\frac{1}{2}$-fath. stations (fig. 4).

In April to June, the increase in numbers of naupliar and protozoeal stages in plankton hauls over those during the previous 3-mo. period indicated increased spawning. Planktonic stages were widely distributed over the survey area; the greatest concentrations were off the Texas coast in the depth zone bounded by the 15- and 25-fath. contour lines.

The high catch of protozoeal stages indicated continued spawning in July to September. Planktonic-stage *Penaeus* species were more widely distributed than in any previous period and were concentrated most heavily along the Texas coast in 15 fath. southeast of Galveston, in $7\frac{1}{2}$ fath. northeast of Corpus Christi, and in $4\frac{1}{2}$ fath. northeast of Brownsville. These three areas are in a zone of high concentration that

Table 1.--Average catch per unit of effort of six genera of shrimp, northwestern Gulf of Mexico[1]

Genus	1962			1963		
	East	West	Both areas	East	West	Both areas
Penaeus	8	13	10	10	38	22
"TX"[2]	15	36	25	16	97	49
Sicyonia	7	21	14	2	20	10
Solenocera	5	7	6	3	5	4
Parapenaeus	1	2	2	1	< 1	< 1
Total	36	79	58	32	160	85

[1] Average number of planktonic stages per 100 $m.^3$ (3,534 $ft.^3$).
[2] *Trachypeneus* and *Xiphopeneus*.

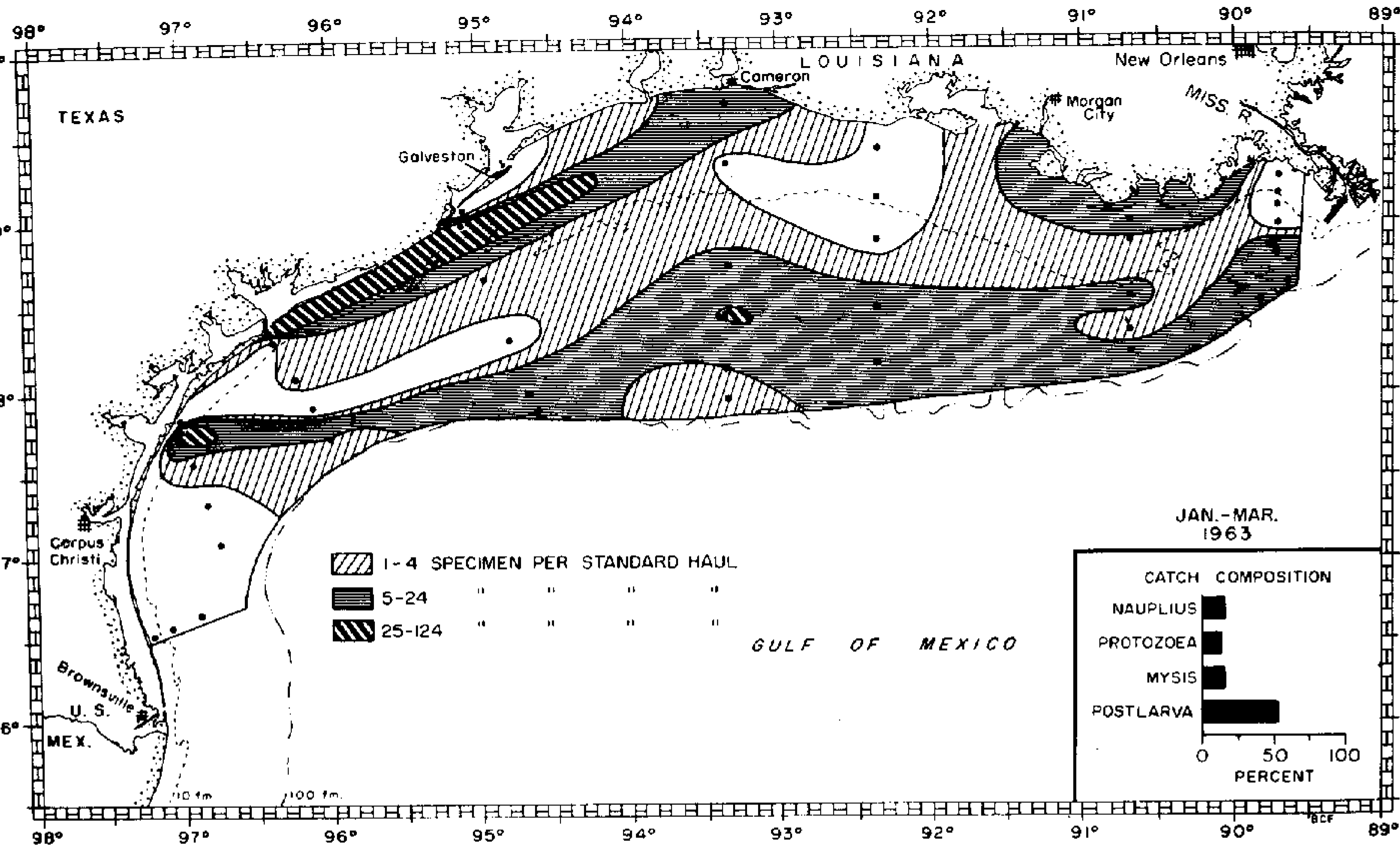

Figure 4.--Distribution of planktonic stages of species of Penaeus in the northwestern Gulf of Mexico, January to March 1963.

extended from 15 fath. south of Cameron, La., to the westernmost transect northeast of Brownsville, Tex. To the east, a small concentration occurred just west of the Mississippi Delta in 15 and 40 fath.

In October to December, spawning continued to increase as is shown by the greater numbers of early larval stages in plankton hauls. Although planktonic stages were again widely distributed, they occurred primarily in waters outside the 7½-fath. contour. Highest concentrations were restricted generally to a zone between the 15- and 25-fath. contours in the west and to the 25-fath. zone in the east.

Seasonal Trends in Abundance, 1962 and 1963

Trends in the abundance of Penaeus larvae (postlarvae excluded) at comparable depths were similar in 1962 and 1963. In the 7½-fath. depth zone, numbers of larvae increased in the spring, maintained a relatively high level through summer, and decreased in the fall. In 15 to 25 and 35 to 60 fath. of water, two peaks of abundance were evident--one in late spring and early summer and the other in the fall. Greatest numbers of larvae were taken during the fall. In both years, about 22 percent of the total, weighted larval catch occurred in 7½ fath., 58 percent in 15 to 25 fath., and 20 percent in 35 to 60 fath. (fig. 5).

Earlier data indicated that larval abundance was closely related to water temperature, particularly landward of 25 fath. In 1962,

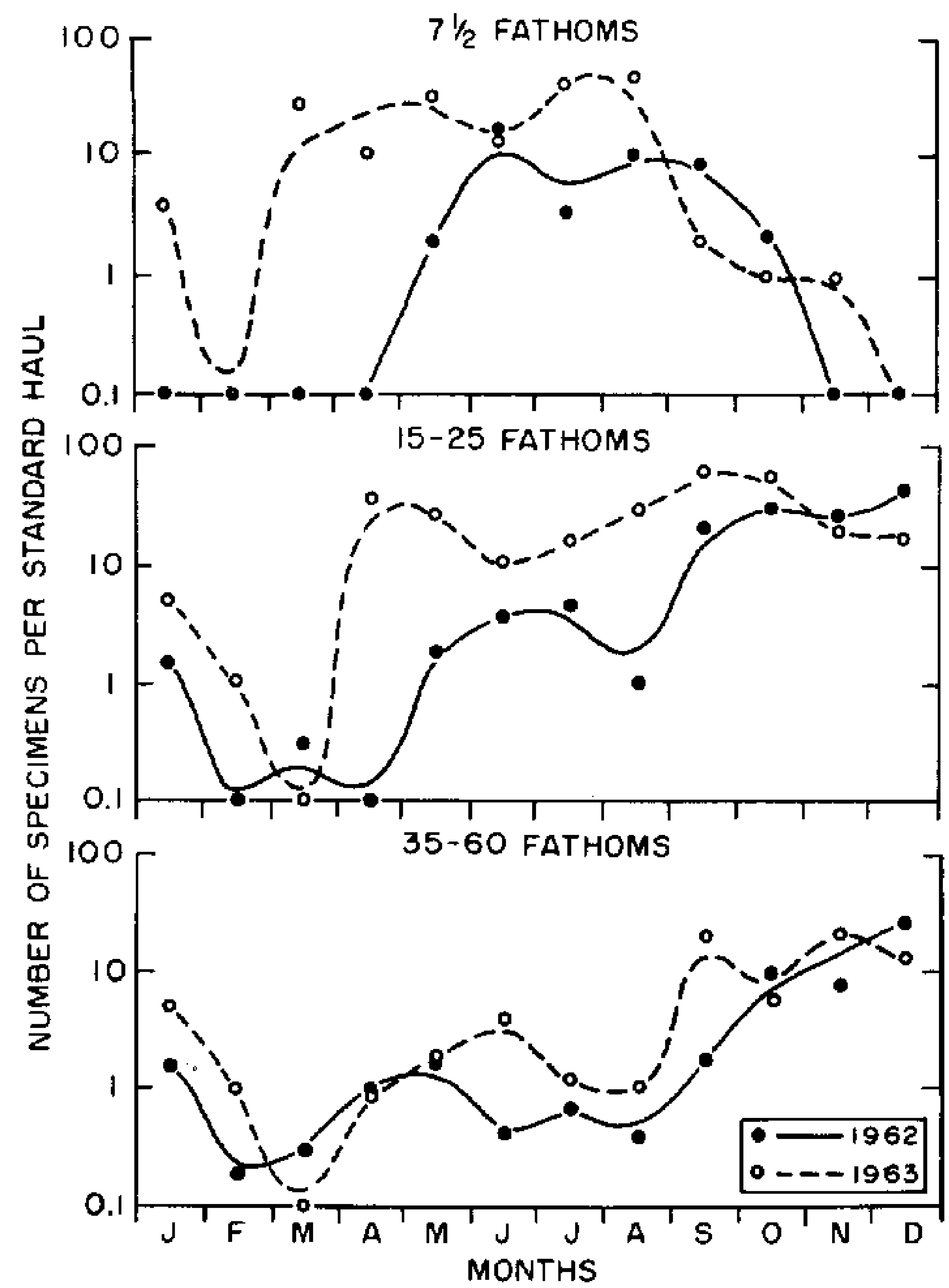

Figure 5.--Abundance of Penaeus larvae in depths of 7½ fath., 15-25 fath., and 35-60 fath., 1962.

seasonal trends in larval abundance and seasonal changes in water temperature seemed to be related. In 1963, however, this relation was not as apparent; it seems that spawning, larval abundance, or both, may not be related to a specific temperature but perhaps to changes in temperature.

Noncommercial Species

Distinct patterns of depth distribution and trends of abundance were evident for the noncommercial planktonic-stage penaeids in our plankton hauls. Species of Sicyonia and "TX" occurred most frequently inside the 25-fath. contour, whereas species of Solenocera and Parapenaeus were most frequently found in deeper waters. In addition, species of Sicyonia "TX" and Solenocera occurred in greater numbers between August and October; species of Parapenaeus were most abundant in January and February.

Clarence C. Fischer, Project Leader

IDENTIFICATION AND CULTURE OF SHRIMP LARVAE

The primary aim of this project is to develop methods of rearing penaeid shrimp so that larvae of known parentage may be obtained for comparative morphological studies. During the past year three species have been reared to postlarvae: brown shrimp, pink shrimp, and Trachypeneus similis. A preliminary examination showed that brown and pink shrimp larvae had no significant differences in setation or other easily observed body parts. The ratios of various body parts might be significantly different, but the larvae were too few for a detailed study. Several series of larvae, obtained at different seasons from females of each species, are now being accumulated for examination.

A secondary goal is to determine methods of rearing penaeid larvae en masse to supply shrimp grown under known conditions for physiological and pond-culture studies. In early culture experiments, larvae in limited numbers could be reared to postlarvae only when they were held in enriched sea water, which was changed daily. In recent rearing trials, larvae of both brown and pink shrimp have been reared in sea water in 20-gal. (gallon) mass cultures with disodium salt of the metal chelator E.D.T.A. the only additive.

Development of an effective screening and filtering system (fig. 6) made it possible to discontinue the use of antibiotics during spawning and hatching. One end of a 20-gal. fiberglass tank has been fitted with a nylon screen of a mesh size too small to allow the eggs or larvae to pass through (0.18 mm. or 0.007 in.). Water is then pumped from the screened end of the tank and recirculated through a filter of crushed oyster shell without damage to the larvae. Water is recirculated through the filter from the time the ripe shrimp is placed in the tank until the eggs hatch and the first protozoeal stage begins to feed. Subsequently, the water is filtered only for 1 hr. a day. A metering pump furnishes a constant supply of the diatom, Skeletonema species, as food. A light beneath the tank attracts the larvae on the bottom; however, an air bubbler in the tank disperses the larvae throughout the tank.

Using the equipment and techniques described above, we have successfully reared brown and pink shrimp. During these two experiments, temperatures ranged between 26° C. (78.8° F.) and 27° C. (80.6° F.), and salinity varied from 24.1 p.p.t. to 20.5 p.p.t. Under these conditions the first postlarva was observed on the 13th day after hatching, and almost all larvae had metamorphosed to postlarvae by the 15th day.

In an effort to determine optimum conditions for population growth and maintenance of organisms to be tested as food for larval shrimp, four diatoms, two flagellates, and three dinoflagellates were each cultivated in nine different media. Although cell multiplication varied with the species and media tested, each organism produced the greatest number of cells in Miquel's sea water with soil extract. The population did not increase in sea-water controls. A similar experiment tested the effects of five fertilizers on population growth of the diatom, Skeletonema species. In promoting rapid growth, fertilizer composition appeared less important than its concentration. Dilutions in the range 1/10,000-1/100,000 induced greater increases in cell number than did stronger or weaker concentrations.

Two attempts to maintain 50-gal. cultures of Skeletonema with commercial fertilizers as a nutrient source in water from the laboratory's sea-water system proved unsuccessful; later, however, following the work of Johnston (1964),[8] we found that by adding E.D.T.A. in a concentration of 1 g. (gram) per 100 l. (liters) (about 15 g. per 25 gal.) of sea water, we could easily maintain mass cultures. The culture tanks are indoors, well aerated, and constantly illuminated with about 1,000 ft.-c. (foot-candles) of fluorescent light. Once the diatoms reach a peak density, we have maintained vigorous cultures by drawing off and replacing two-thirds of the water in the tank daily.

Work continued on how various environmental conditions and foods affect larval development. We completed one temperature experiment with brown shrimp larvae. Larvae

[8] Johnston, R., 1964. Sea water, the natural medium of phytoplankton. II. Trace metals and chelation and general discussion. J. Mar. Biol. Ass. U.K. 44 (1): 87-109.

reared at 18° C. (64.4° F.) and 21° C. (69.8° F.) died during the molt to first protozoeae; first postlarval stage was reached in 15 days at 24° C. (75.2° F.), in 12 days at 27° C. (80.6° F.), and in 11 days at 30° C. (86.0° F.). Six different organisms were tested as food for Trachypeneus similis larvae, with Skeletonema species as a control. Gymnodinium splendens gave the best survival; the Dunaliella species and Thalassiosira species, and a Euglenoid all gave better survival than Skeletonema; and two unidentified dinoflagellates gave poorer survival.

Harry L. Cook, Project Leader

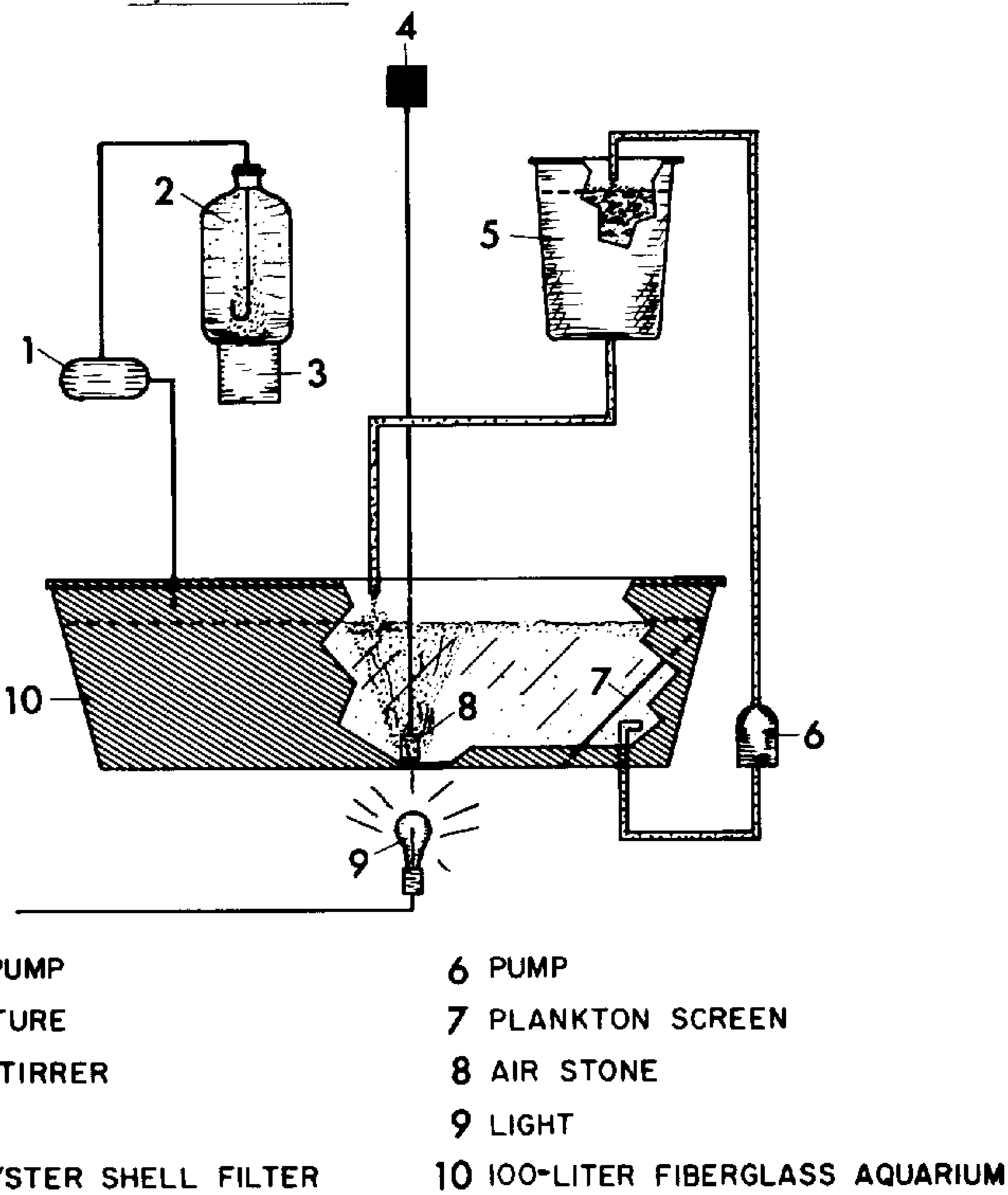

Figure 6.--Filtering system for mass culturing of penaeid larvae.

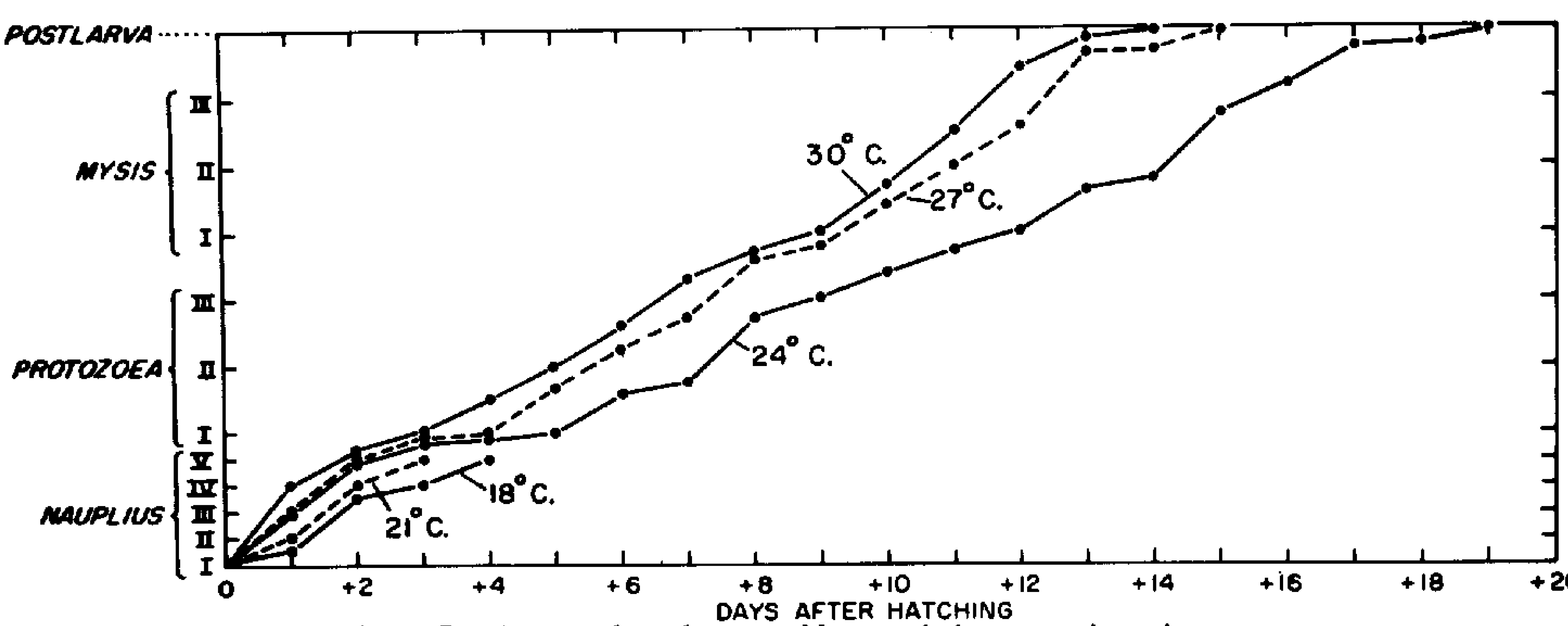

Figure 7.--Average larval stage of brown shrimp at a given time.

CULTIVATION OF SHRIMP IN ARTIFICIAL PONDS

This project was started in December 1964 to determine the feasibility of culturing shrimp commercially in ponds under seminatural conditions. More specifically, this research is designed to give information on the cost of pond construction and maintenance and provide data on environmental factors within the pond that may affect growth and survival rate of pond-held shrimp.

Procedures

A different rearing technique is being attempted in each of the two ponds (100 ft. by 50 ft. by 4 1/2 ft.). One pond (circulating-water pond) has a continuous exchange of water filtered through oyster shell, and the shrimp are fed daily with a prepared diet. In the other pond (static-water pond), we add water only to compensate for evaporation loss, and add commercial fertilizer to promote the growth of plankton for natural food for shrimp (fig. 8).

Stocking of the ponds with postlarval brown shrimp required 4 days and was completed April 1, 1965. Final production was tentatively estimated at 125 lb. (pounds) of 26- to 30-count shrimp per pond. Limited data on mortality of reared shrimp indicated that to attain this goal, an initial stocking of about 9,000 postlarval shrimp would be required in each pond. These postlarvae were collected as they migrated into the Galveston estuarine system and were "hand-picked" in an attempt to eliminate predators. Three wk. after stocking, we began sampling shrimp weekly to obtain information on their growth.

Water samples have also been collected periodically and analyzed for dissolved oxygen, pH, nitrite, nitrate, total and inorganic phosphate, and chlorophyll. In addition, we have measured salinity and temperature daily. Average weekly temperature and salinity values obtained during the first 11 wk. of the initial experiment are presented in table 2.

Preliminary Results

In the static-water pond a lush growth of plankton was obtained during the first 3 wk. after stocking. Plankton counts showed an increase in numbers of flagellates and dinoflagellates followed by an increase in rotifers. At the end of the 3-wk. period, we tried unsuccessfully to catch shrimp. When we drained the pond, we found no shrimp. The bottom of the pond had a smelly black layer. The shrimp mortality was probably caused by low oxygen content, which we attribute to the lush growth and death of plankton.

This pond, after being thoroughly flushed and refilled, was again stocked with about 6,000 postlarval brown shrimp on May 6. Water fertility was not adjusted, for we felt that residue from the fertilizer originally used might be ample to ensure adequate plankton growth. Data obtained on growth in length and weight of shrimp during the next 6 wk. supported this assumption. Growth in length averaged 1.5 mm. (0.06 in.) per day, and in weight 0.07 g. (0.0025 oz.) per day (fig. 9).

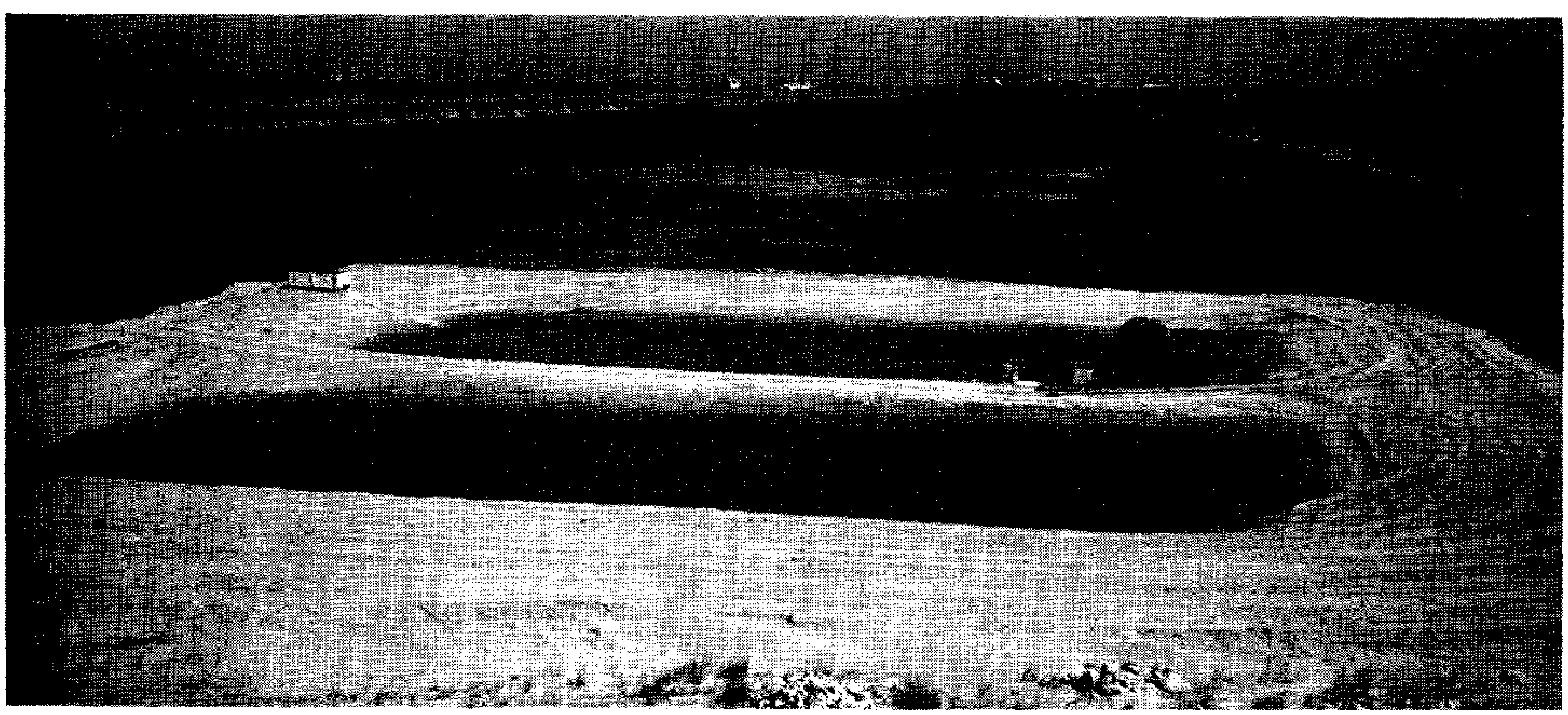

Figure 8.--Ponds dredged for cultivation of shrimp.

Table 2.--Average weekly temperatures and salinities

Week	Circulating-water pond			Static-water pond		
	Salinity	Bottom temperature		Salinity	Bottom temperature	
	P.p.t.	°C.	°F.	P.p.t.	°C.	°F.
1..........	25.6	20.0	68.0	27.4	21.0	69.8
2..........	18.1	23.0	73.4	23.8	25.0	77.0
3..........	24.4	24.5	76.1	28.0	24.0	75.2
4..........	23.6	24.5	76.1	28.0	24.0	75.2
5..........	25.3	23.5	74.3	(1)	(1)	(1)
6..........	25.4	25.5	74.3	27.0	27.0	80.6
7..........	(2)	26.5	79.7	24.5	27.0	80.6
8..........	(2)	27.0	80.6	23.5	26.0	78.8
9..........	17.8	28.0	82.4	22.5	28.0	82.4
10.........	20.8	28.5	83.3	24.2	28.5	83.3
11.........	18.5	31.0	87.8	21.7	31.5	88.7

[1] Flushing and cleaning of pond.
[2] No observation.

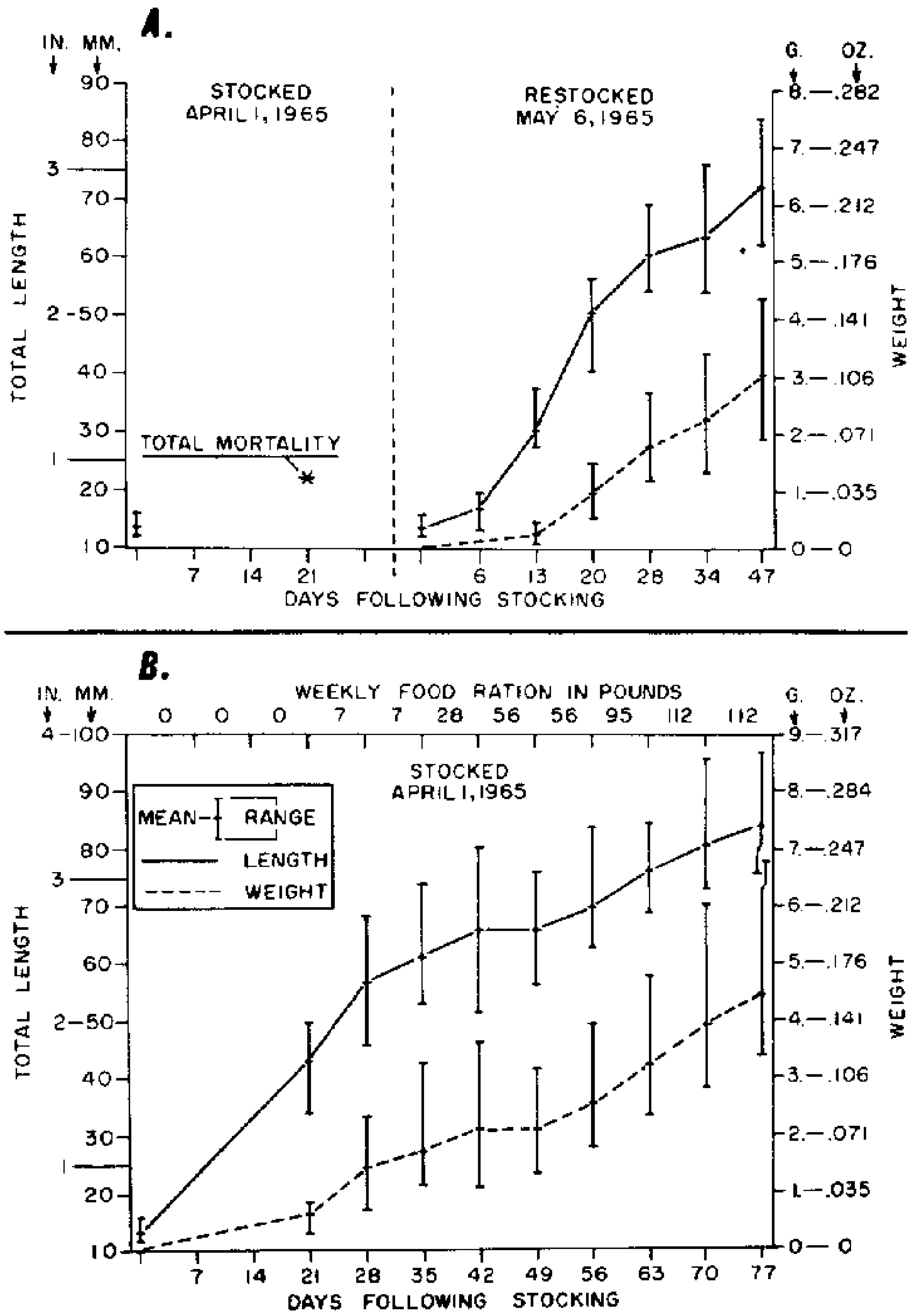

Figure 9.--Growth, measured in average lengths and weights, of brown shrimp reared in static-water pond (A) and circulating-water pond (B).

Results in the circulating-water pond appeared more promising because all the shrimp did not die. Average lengths and weights of shrimp during the first 77 days of this experiment increased at a rate of 0.9 mm. (0.035 in.) per day and 0.06 g. (0.0021 oz.) per day. Weekly variation in growth of length and weight may be due, in part, to the amount of food supplied daily.

Ray S. Wheeler, Project Leader

FLORIDA BAY ECOLOGY PROJECT

This project, started in fiscal year 1964, has two principal objectives: (1) to establish, by quantitative sampling, an index of abundance of juvenile pink shrimp in eastern Florida Bay and (2) to describe the habitat types in the pink shrimp nursery areas of eastern Florida Bay and relate these types to the density of juvenile pink shrimp in each area.

The Study Area

Florida Bay, located at the southern tip of the Florida Peninsula, is an extensive shallow embayment intersected by grass-covered mud banks and mangrove keys. Turney (1958)[9] separated the bay into four subenvironments based upon degree of water circulation, influx of ocean and fresh water, salinity and temperature ranges, and distribution of mollusks. For comparative purposes, we have located sampling sites in two of these subenvironments, and we are considering a third site (fig. 10).

Development of Sampling Equipment

Because we had to measure quantitatively the abundance of juvenile pink shrimp in Florida Bay, we considered several types of

[9] Turney, W. J. 1958. Molluscan distribution in Florida Bay. Shell EPR Rep. 513, 39 p.

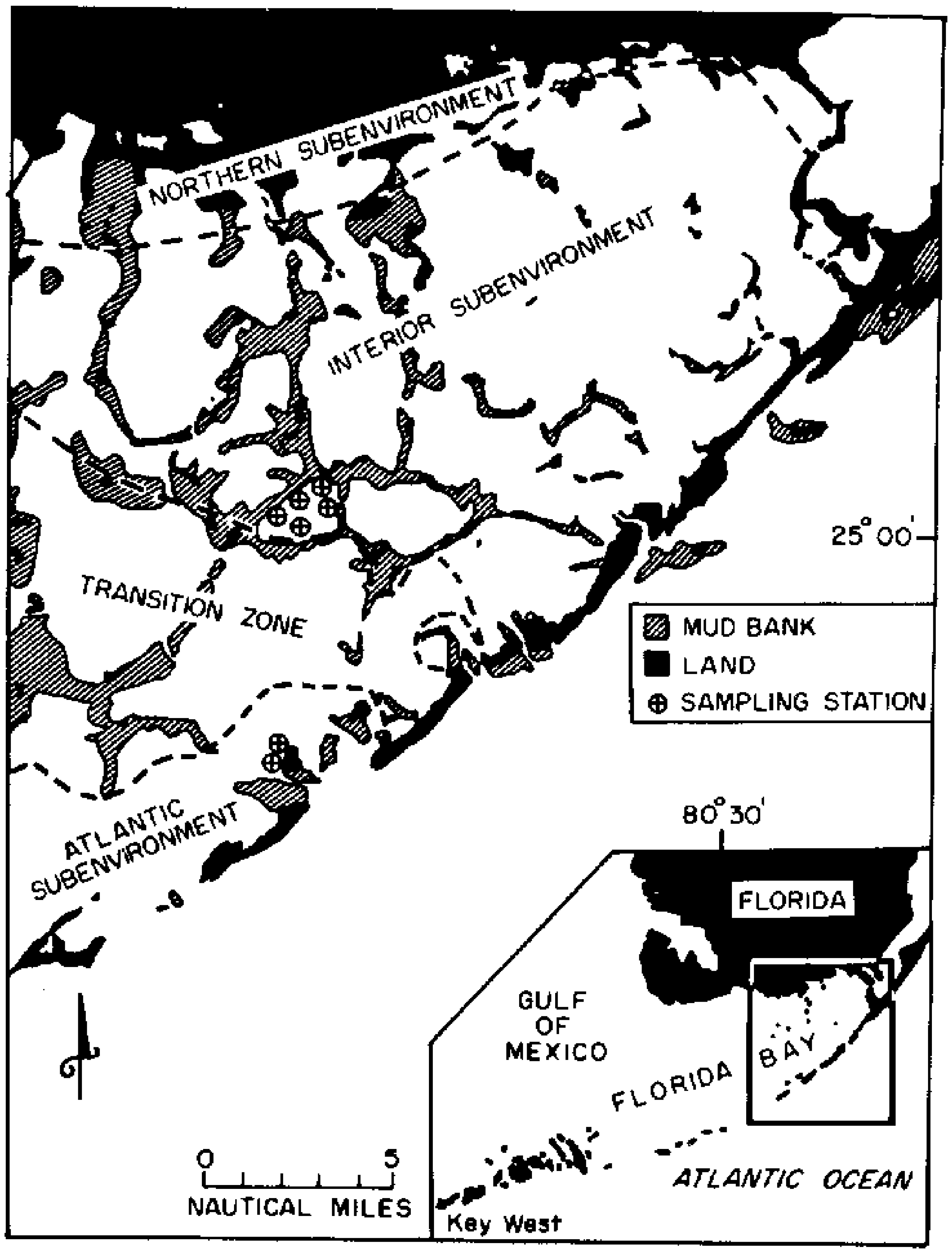

Figure 10.--Subenvironments in Florida Bay.

Figure 11.--Sampler designed for use with chemical repellant.

sampling gear. It was learned that trawls and stationary traps with directive leads had limitations that made them unsatisfactory. We then began developing equipment to adequately sample shrimp from the substrate enclosed under a metal container.

In the first device (fig. 11), the release of a chemical repellant within the container drove the enclosed shrimp and associated organisms into an attached nonreturn trap. This sampler was effective in obtaining a quantitative sample of shrimp except when very small shrimp were present. Shrimp less than about 20 mm. (0.8 in.) total length did not avoid the repellant as did larger individuals.

We also developed a suction dredge. This dredge operates on the venturi principle. Water is pumped at 35 lb. per sq. in. pressure through a pressure nozzle into a venturi tube. A vacuum is created, and strong suction forms in the attached sampling hose. Water is then discharged into a collecting screen.

To determine the most efficient use of the 3-in. sampling hose, we tested several methods of enclosing the area to be sampled. Enclosures tested were: (1) a trough, 1/12 m.^{2} (0.9 ft.^{2}), with sliding top through which the suction head is inserted; (2) a cylinder, 1/10 m.^{2} (1.1 ft.^{2}), from which all water can be exhausted; and (3) a hood, 1/10 m.^{2} (1.1 ft.^{2}), attached to the suction head. With the first two enclosures the suction head captured all shrimp enclosed, but the sampler could be easily used only in shallow water. With the hood attached, the gear functioned satisfactorily in deeper waters but did not capture all of the shrimp enclosed.

To eliminate problems encountered in the use of enclosures, the suction head was attached to a specially constructed sled (fig. 12). Two parallel keels or guides were affixed on the underside of the sled and the suction head was mounted between the guides at right angles to the substrate. These guides limit the width of the swath "vacuumed" to 80 mm. (3.1 in.). A hand winch is used to draw the sled at a standard speed. Pump, venturi tube, intake, and discharge collection screen are supported by a specially designed raft that is attached to and drawn behind the sled by the sampling hose. This unit can be quickly taken apart and put together and is readily transported on a 20-ft., shallow-draft boat.

In comparative trials with a beam trawl in 60 cm. (23.6 in.) of water, the average catch by suction sampler was 13.5 Penaeus shrimp per square meter vs. 1.4 shrimp per square meter by the beam trawl. In addition to taking penaeid shrimp, the suction sampler collected caridean shrimp, amphipods, isopods, crabs, mollusks, worms, and fish. We are still studying the efficiency of the suction sampler in capturing all or a known percentage of the shrimp lying in its path.

Figure 12.--Sled with suction head affixed between parallel guides.

Sampling procedure

Sampling stations were established in shallow water near the shores of salt-water lakes within Florida Bay. These stations include a variety of habitat types in respect to substrate and vegetative cover. These stations are 12.5 by 12.5 m. (186.9 sq. yd.) and are marked so that repeated samples can be obtained from the same area. The inner border of each station parallels the shoreline. Exploratory sampling revealed that postlarval and juvenile shrimp are often concentrated in marine vegetation near the low-water mark in a zone paralleling the shoreline. (Samples 1 to 4 in table 3 were taken parallel to the shoreline and sample 5 perpendicular to the shoreline.) For a more accurate measure of abundance, therefore, the sampler is drawn perpendicular to the inner and outer borders of the station. At each station, two tows are made at not less than 2-wk. intervals. Possible habitat changes due to repeated sampling are minimized because such a small proportion of the station is disturbed.

Preliminary Results

Sampling began April 1965 after we made final refinements to the suction dredge. Results obtained in three areas are compared in table 4.

The lack of quantitative measures of pink shrimp abundance in the past precludes more than a general evaluation of pink shrimp densities in Florida Bay at this time. When compared with the Biscayne Bay values of 7.0 and 2.2 shrimp per square meter (10.8 ft.^{2}), densities of 1.5 and 0.8 shrimp per square meter in Florida Bay may be low.

Thomas J. Costello, Project Leader
and Donald M. Allen

Table 3.--Postlarval and juvenile pink shrimp zonation in shallow-water sea-grass beds in Biscayne Bay[1]

Sample number	Water depth	Shrimp per m.^{2} (10.8 ft.^{2})	Total length of shrimp
	Cm. (In.)	No.	Cm. (In.)
1	15-20 (5.9-7.9)	13	12-25 (0.5-1.0)
2	20-23 (7.9-9.1)	9	12-30 (.5-1.2)
3	30 (11.8)	2	15-25 (.6-1.0)
4	36 (14.2)	0	- -
5	15-30 (5.9-11.8)	7	12-40 (.5-1.6

[1] Samples collected March 1965.

Table 4.--Comparison of postlarval and juvenile pink shrimp abundance between interior Florida Bay, Atlantic Florida Bay, and Biscayne Bay, March to May 1965

[Numbers within parentheses indicate number of samples]

Date	Juvenile pink shrimp per 1 m.^{2}		
	Interior[1] subenvironment Florida Bay	Atlantic[1] subenvironment Florida Bay	Biscayne Bay
	No.	No.	No.
Mar. 29...	-	-	7.0 (3)
Apr. 20...	0.8 (10)	-	-
May 4.....	-	-	2.2 (4)
May 13....	.8 (10)	1.5 (2)	-
May 16....	.3 (10)	.5 (2)	-

[1] See figure 10 for locations.

ECOLOGICALLY ASSOCIATED ORGANISMS

We are studying some of the many organisms, mostly fishes and crustaceans, that are closely associated with, and often impede, the harvest of Gulf coast shrimp. Little is currently known of how these forms affect commercial shrimp populations through predation, crowding, or competition for food.

Bottomfish samples collected monthly through December 1964 at 36 sampling stations on the commercial offshore shrimp grounds in the northwestern Gulf of Mexico were examined, and the resulting data were prepared for analysis. We collected samples with a 45-ft. 2-in. stretched-mesh, flat shrimp trawl equipped with rollers. At each station, after we weighed the total finfish catch, we saved a subsample weighing about 7 1/2 lb., which was brought to the laboratory for determination of species composition. We are now analyzing these data and also 2 1/2 yr. of data compiled by the Industrial Fishery Program to determine seasonal, depth, and spatial relative abundance of finfish species that live on the shrimp grounds. Upon completion of this survey we will study the life histories of certain species of fishes so we can understand better their relations to the shrimp populations.

The average catch per unit of effort in 1964 of all fish species combined was about 2 to 4 times greater off Louisiana than off Texas. These catch-effort averages, which

Table 5.--Average fish catch per unit effort over the Continental Shelf, northwestern Gulf of Mexico in 1964

Region	Depth (fath.)			
	4	7 1/2	15	25
	Pounds/hour	Pounds/hour	Pounds/hour	Pounds/hour
Texas.....	50	65	65	90
Louisiana[1]	125	240	225	175

[1] West of Mississippi River.

are reported as pounds per hour, were very similar to those calculated from samples taken at the same depths in 1963 (table 5).

In a preliminary analysis of the data collected off the Texas coast in 1963, the catches per unit effort of 10 finfish species, which constituted over two-thirds of the total poundage of fish caught, were compared seasonally at three depth ranges to the corresponding catches per effort of the two major commercial shrimp species.

White shrimp were more abundant by weight in the inshore waters (4 and 7.5 fath.), whereas brown shrimp were more abundant in middepths (12 and 15 fath.) and offshore (25 and 40 fath.). The peak seasonal abundance of white shrimp was during fall and that of brown shrimp was in summer at middepths and in fall offshore (fig. 13).

Seacatfish, Galeichthys felis, and southern kingfish, Menticirrhus americanus, were most abundant in inshore waters (4 and 7.5 fath.) in summer--the time of offshore movements of juvenile brown shrimp from estuarine nursery areas along the Texas coast. These fish were not taken on the offshore brown shrimp grounds.

Shoal flounder, Syacium gunteri (see fig. 13), as well as Atlantic croaker, Micropogon undulatus; spot, Leiostomus xanthurus; and silver and sand seatrout, Cynoscion nothus and C. arenarius, were taken from all three depth ranges. In the middepth range the greatest catches of the latter four species coincided seasonally with the largest brown shrimp catches.

Rock seabass, Centropristis philadelphicus (see fig. 13), and longspine porgy, Stenotomus caprinus, occurred mostly in the catches from the offshore brown shrimp grounds. None was taken on the white shrimp grounds. Inshore lizardfish, Synodus foetens, had a similar seasonal catch distribution; it occasionally occurred, however, in the catches from the inshore white shrimp grounds.

Donald Moore, Project Leader

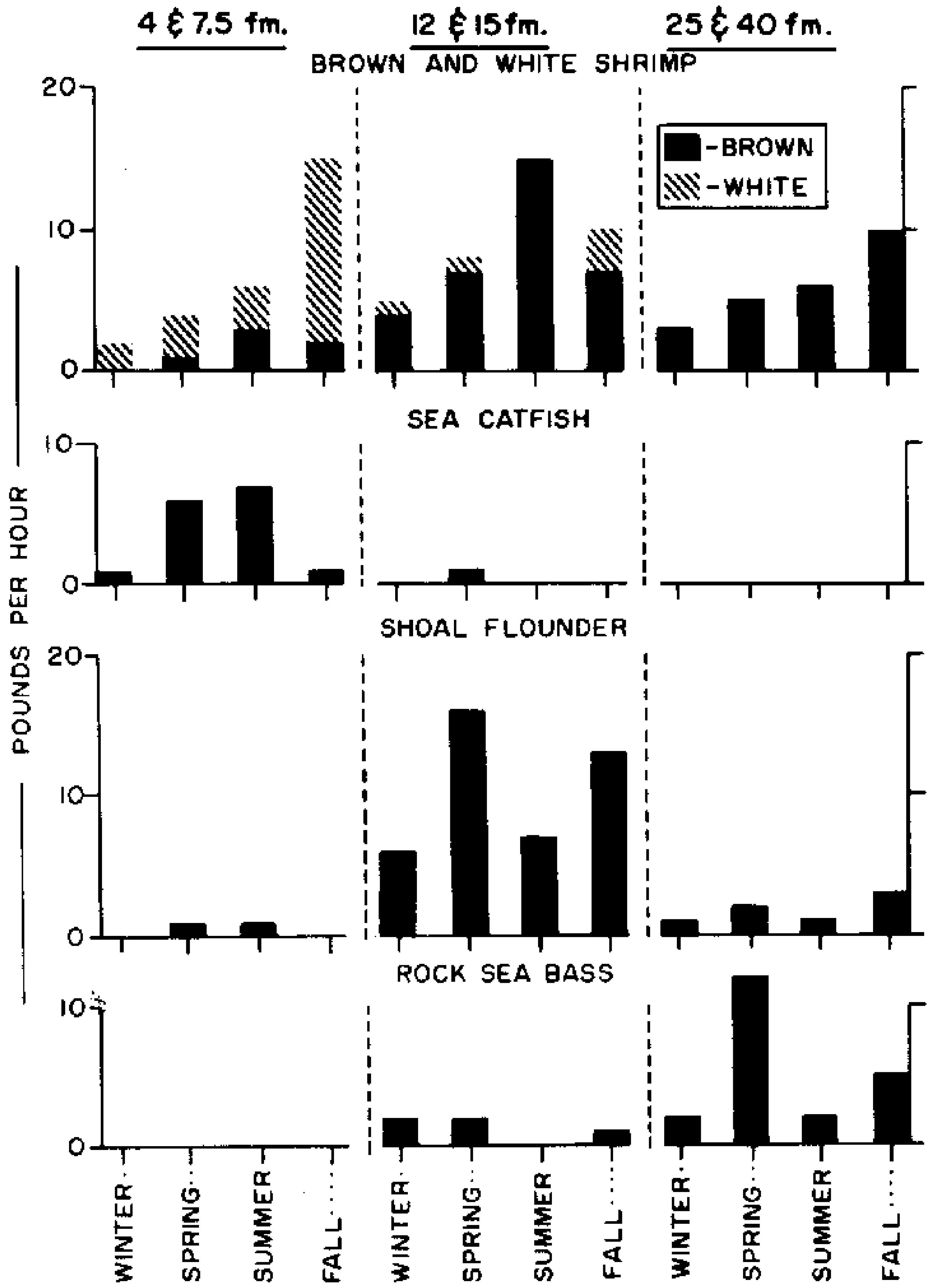

Figure 13.--Catch per unit effort (pounds/hour) by seasons for two--brown and white--commercial shrimp and three finfish--sea catfish, shoal flounder, and rock seabass--occurring in three depth zones off the Texas coast, in 1963. (Winter is Jan.-Mar.; spring, Apr.-June; summer July-Sept.; and fall, Oct.-Dec.)

ABUNDANCE AND DISTRIBUTION OF PINK SHRIMP LARVAE ON THE TORTUGAS SHELF OF FLORIDA

This report covers the final phase of the studies on pink shrimp larvae on the Tortugas shelf. We have now analyzed all data and are preparing a detailed description of the results.

During the past year, we made six cruises to the Tortugas shelf and obtained 154 plankton samples. We stopped sampling in October 1964 and began examining a backlog of samples. The resulting data were then prepared for automatic data processing and analyzed.

In 1963, the production of first protozoeal stages of pink shrimp within a sampling area of 1,000 sq. nautical miles was estimated at 5 trillion individuals. Seasonal variation in larval production was considerable however. The sampling area yielded an estimate of 2.1 trillion first protozoea from January to July 1963 and a threefold increase to about 6.5 trillion over the same period in 1964. For a variety of reasons, however, we believe these estimates may be low.

Analysis of larval and temperature data suggested a relation between spawning intensity and bottom temperatures. The greatest amount of spawning over the past 6 yr. has occurred when temperatures exceeded 27° C. (80.6° F.); usually less than 10 percent of each year's spawning occurred when temperatures were below 24° C. (75.2° F.).

Spawning intensity appeared to be related to moon phases. Most spawning was around the full-moon period and least at new moon. It appears possible to estimate from catch curves the apparent mortalities of the larvae as they proceed through successive larval stages. Mortality for various stages varied in a consistent fashion between stations; some stations were consistently losing younger stages, whereas other sampling stations (possibly located along the migration routes) were consistently receiving older stages. Thus, because spawning occurred at all stations, the apparent survival rates of the larvae varied according to station, and the survival rates could be used to indicate migration patterns. Survival throughout larval life appears to be nearly constant, averaging 80.4 percent per day; therefore, we estimate that only 0.14 percent of the first protozoea produced survive to postlarval stages that enter the nursery grounds at an average age of 35 days.

A single survey cruise (42 stations) undertaken in October 1964 showed concentration of larvae along the margin of the Gulf Stream south of the Florida Keys. It is possible that migration between the Tortugas spawning grounds and the Florida mainland nursery grounds may take place via Rebecca Channel and the Gulf Stream. If so, the larvae would arrive at a point within 20 to 30 miles of the nursery grounds only 6 days after leaving the spawning area.

The release and subsequent recovery of seabed drifters have provided further evidence that currents in the Tortugas-Florida Bay area are weak--about 1 mile per day--and that the movement is primarily toward the southwest. This current might prevent movement of larvae in a direct line between the spawning grounds and the Everglades nursery areas, thus adding weight to the possibility that the Gulf Stream is the main mode of transportation.

G. P. Idyll and J. L. Munro, Project Leaders

Institute of Marine Science,
University of Miami
(Contract No. 14-17-0002-98)

ABUNDANCE OF JUVENILE PINK SHRIMP ON THE EVERGLADES NATIONAL PARK NURSERY GROUNDS

The primary aims of this project are to describe the relative abundance of pink shrimp migrating out of the Whitewater-Coot Bay estuary (via Buttonwood Canal) in Everglades National Park and to determine the environmental and biological factors that influence this abundance.

Estimates of relative abundance are based on the catches of emigrating shrimp collected in a large channel net fished in Buttonwood Canal. Regular monthly samples have been taken since January 1963. In most months, we sampled ebb tides on consecutive nights and made an abundance estimate from the combined samples of 2 nights. These data show that if weather remains reasonably steady, the abundance from night to night shows only moderate variation, especially around the time of the full moon. From our analysis of 2 yr. of data, it appears that periods of high relative abundance occur in spring, summer, and early fall, but that interyear variation is considerable.

Periods of low relative abundance occur during the late fall or winter and in the spring. In 1963 and 1964, the spring low followed immediately after the spring peak of relative abundance.

During 2 yr. of sampling, the monthly mean size of the shrimp (sexes combined) ranged from 9.9 to 18.0 mm. (0.38 to 0.71 in.) carapace length and averaged 14 mm. (0.55 in.). In general, the smallest shrimp appear at times of high relative abundance. Annual sex ratios were very close to 1:1 in 1963 and 1964.

Secondary objectives of the study are to examine the relation between the abundance of shrimp migrating out of the nursery area and subsequent commercial catches on the Tortugas fishing grounds and to develop gear and techniques that can be used to measure shrimp migrations from an estuary.

The relation of relative abundance of juvenile shrimp in Buttonwood Canal catches to commercial landings of the smallest size category of pink shrimp (68 count and over) shows wide variation. It is best described by using a 2-mo. lag for migrating shrimp of less than 12 mm. (0.47 in.) and by using a 1-mo. lag for shrimp of 12 mm. (0.47 in.) or larger. Although variations do exist, the numbers of small shrimp moving through Buttonwood Canal may provide a reasonably reliable index from which to predict numbers of shrimp that will subsequently appear on the fishing grounds.

One yr. of sampling, with 13 small nets placed from top to bottom across the canal, has provided information on the distribution of migrating pink shrimp in Buttonwood Canal. Results of this study, made during all moon phases, suggest that most consistent numbers of shrimp are on the surface during full moon. During the new moon the percentage of shrimp taken in surface nets averaged 76 percent (range 47 to 98 percent) of the total catch, and during the full moon the numbers averaged 92 percent (range 79 to 99 percent). The considerable variation found in earlier wing-net samples (obtained in the top 1 m. (3.3 ft.) of water) was probably caused by sampling without regard to moon phase. Recent wing-net and channel-net samples taken simultaneously during the time of the full moon in February, March, and April have shown a consistent relation. The variation in abundance estimates observed from wing-net samples can be reduced by fishing during full-moon periods when the shrimp are close to the surface.

C. P. Idyll, E. S. Iversen, and B. Yokel, Project Leaders

Institute of Marine Science, University of Miami (Contract No. 14-17-0001-99)

SHRIMP DYNAMICS PROGRAM

This program is concerned with developing a sound basis for management of shrimp resources in the Gulf of Mexico. The general philosophy underlying our work is that shrimp fisheries should be regulated to provide the maximum return to fishermen, in terms of the weight or value of shrimp harvested, but under conditions that do not reduce future returns. In this context, future returns refer to production in years to come as well as to harvests that might be made if a brood of shrimp were permitted to grow to a larger size.

Management regulations currently applied to shrimp stocks in the Gulf include minimum size laws, net size and mesh regulations, catch quotas, and closed seasons. Most regulations apply to inshore waters and are designed to protect small shrimp until they reach a size acceptable to local markets. Pressures that occasionally develop from changes in marketing practices or in consumer demands cause groups in the shrimp industry to challenge the rationale behind such regulations or to insist that more restrictive laws be enacted and enforced. Conflicts most commonly arise when a stock of shrimp must supply two types of markets--one that requires small shrimp and another that deals in large shrimp. To answer problems of this nature and to evaluate the merits of various regulatory measures, we must make critical studies of shrimp stocks from several points of view.

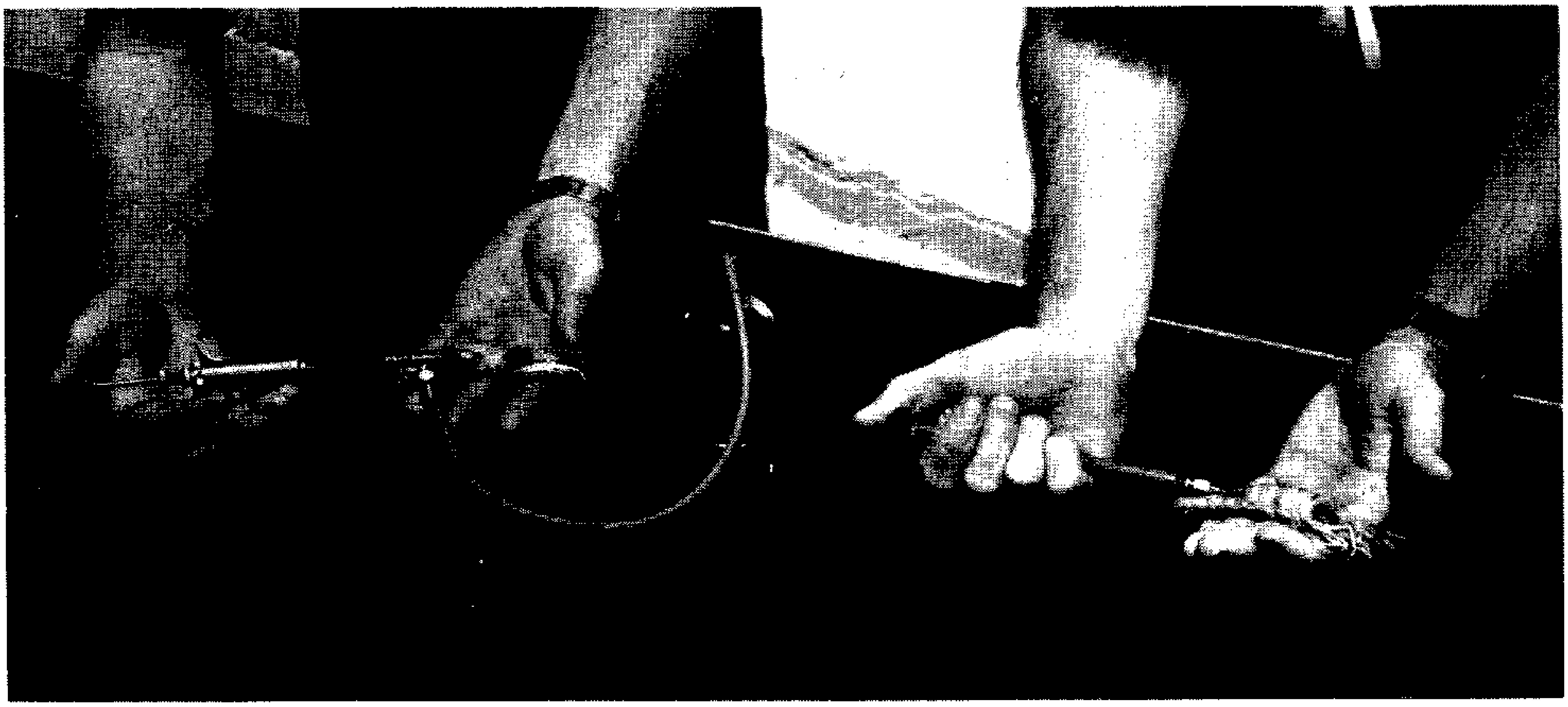

Figure 14.--Staining shrimp for mark-recapture studies.

Major research of this program seeks to determine the optimum size at which shrimp should be harvested. An answer to this question can be obtained rather easily when we have good estimates of the rates of growth and mortality of shrimp. Good estimates, however, are difficult to obtain because shrimp live in a dynamic environment where growth and mortality change continually in response to seasonal differences in temperature, food supply, predation, fishing pressure, etc. Each of the projects within the program is obtaining information needed to describe some aspects of shrimp growth and mortality.

A further means to ensure that fishermen are able to realize maximum returns from shrimp available for harvest is to provide advance indications of where and when good catches can be made. We have made substantial progress in predicting the abundance of brown shrimp from the numbers of postlarvae caught 2 or 3 mo. earlier. Forecasting the abundance of pink and white shrimp has not been perfected, but we have evidence to suggest that this too can be accomplished.

Richard J. Berry, Program Leader

MARK-RECAPTURE EXPERIMENTS

Modern theories of fishery management consider the simultaneous losses and additions in weight that occur in a population and attempt to find the point in time at which these two opposing factors are of equal magnitude. This point represents the average age at which individuals in a population should be harvested to obtain the greatest yield in weight. A practical method for estimating rates of losses and additions to shrimp populations is by mark-recapture experiments in which biological stains are the marking agent. Records of the total fishing effort expended by the fishery in catching marked shrimp are used to estimate population losses resulting from fishing and natural mortalities. Gains in population weight are calculated from the growth of the marked shrimp caught in the fishery. The following paragraphs describe such a mark-recapture experiment on the Tortugas grounds in early February 1965.

The Tortugas shrimping grounds include an area about 50 by 80 miles off the southwestern coast of Florida. Water depths on the grounds range from about 9 fath. on the east to 30 fath. on the west. The fishing fleet, which includes 200 to 400 vessels between October and May, concentrates in depths of 10 to 20 fath. in an area that covers about a quarter of the total fishing grounds.

Previous mark-recapture experiments on the Tortugas grounds formed a basis for the present study. We knew that shrimp moved slowly in a northwesterly direction over the grounds and that marked shrimp are available for capture during a 2- to 4-mo. period after release. Therefore, stained shrimp released in the eastern portion of the grounds in early February should be recaptured from that time until the fleet moves elsewhere in late May. Because measures of fishing and natural mortality obtained from prior experiments have included a range of values, we wished to obtain several independent estimates from this stfidy in order to determine average values under existing conditions. Further objectives were to obtain information on how much shrimp grew during early spring and how they dispersed over the fishing grounds.

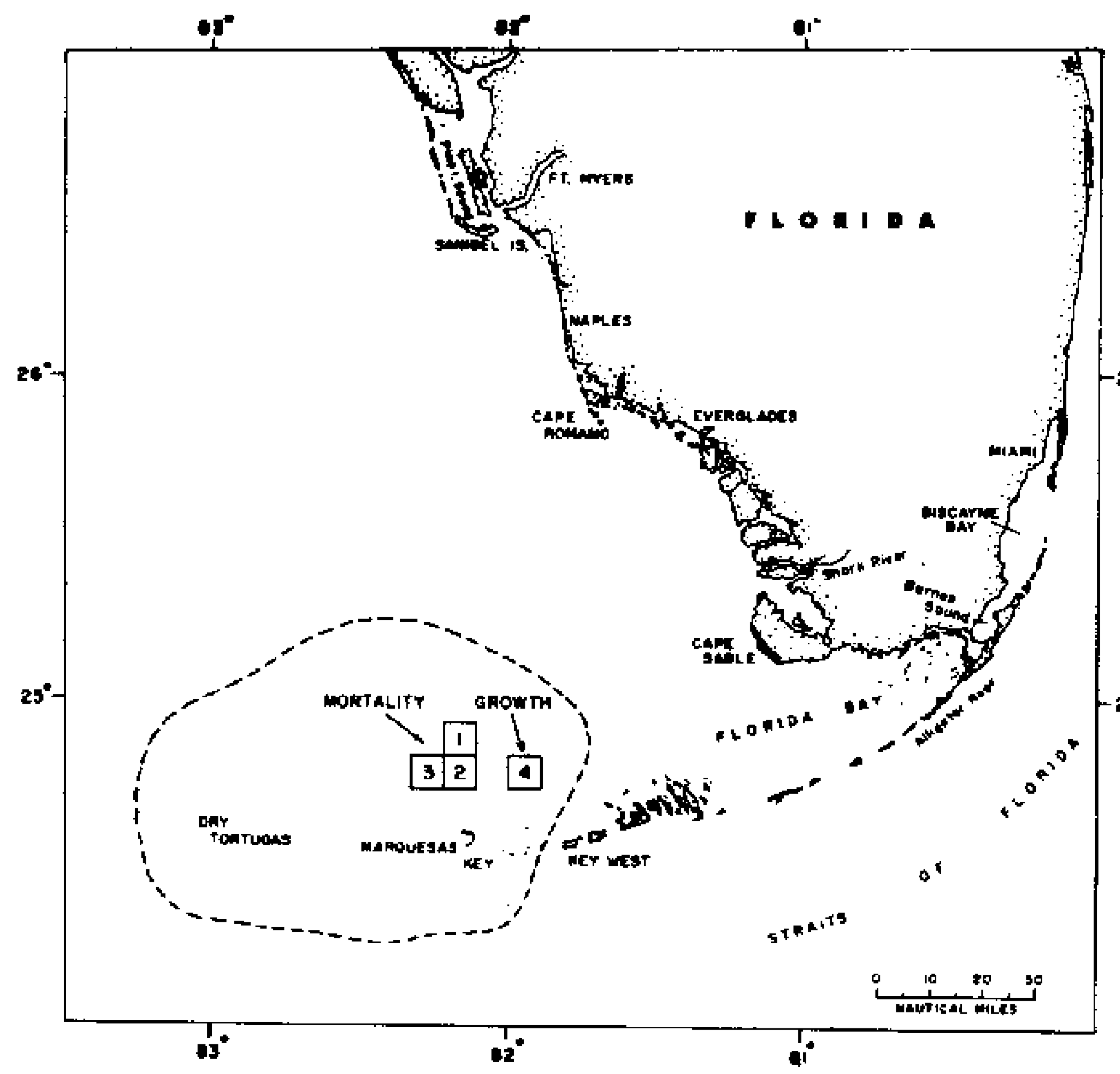

Figure 15.--Release sites for marked pink shrimp released on the Tortugas grounds.

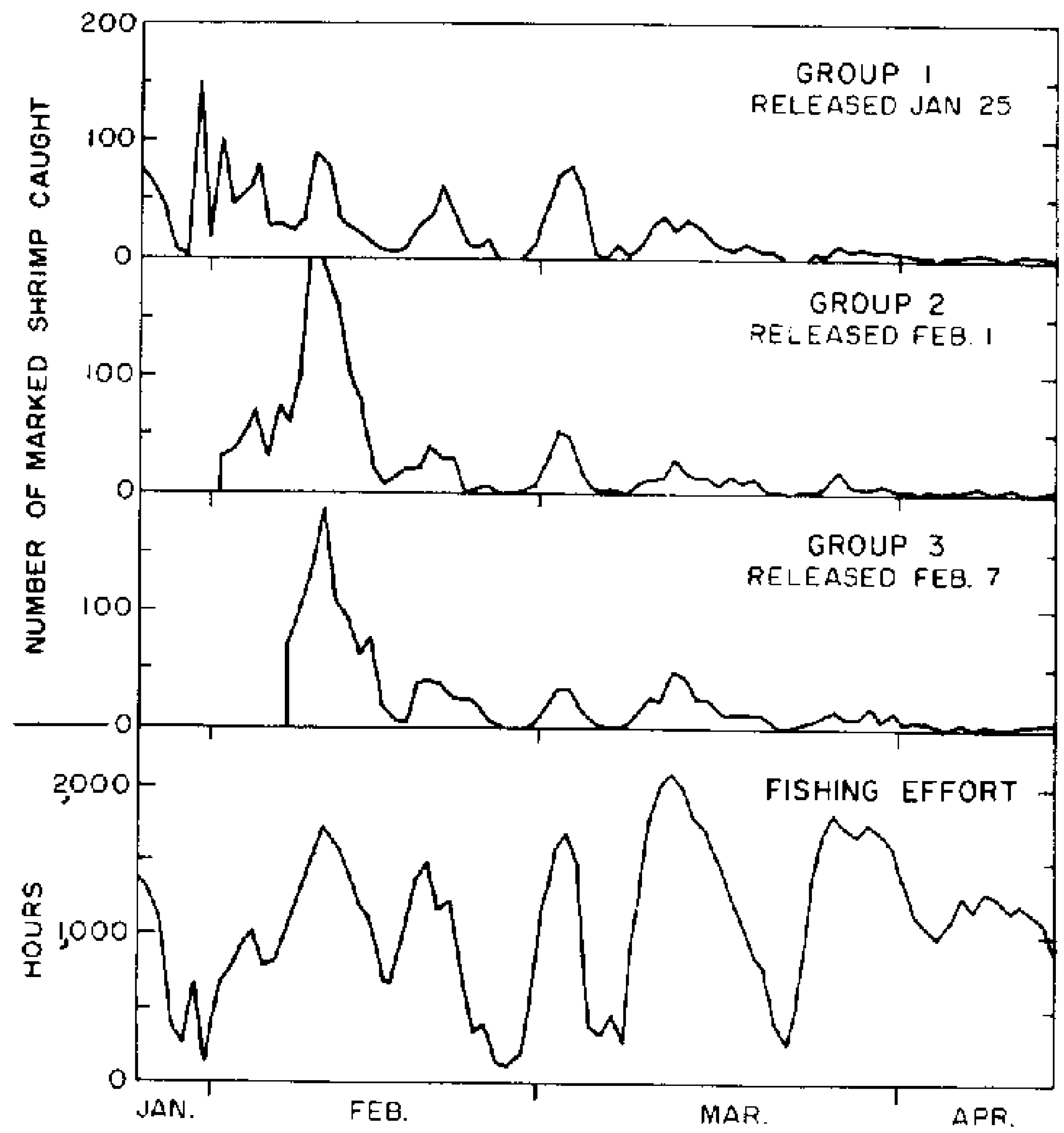

Figure 16.--Comparison of the number of marked shrimp caught and fishing effort, January 25 to April 14, 1965.

To obtain estimates of mortality, we released three separate groups of distinctively marked pink shrimp in an intensively fished part of the grounds (fig. 15). To obtain growth information, we stained and released near the eastern edge of the fishing grounds a fourth group, consisting of small shrimp of a restricted size range (3.8 to 4.1 in.). Details concerning each group appear in table 6.

Calculations of rates of fishing and natural mortality are based on the number of marked shrimp recaptured by the fishery. The two causes of death can be separated when an accurate record of fishing effort is available. Our interviews with the vessel crew members provide information on the amount of fishing effort and where marked shrimp are caught.

Figure 16 illustrates fluctuations in fishing effort and in the number of marked shrimp recovered during the first 80 days of the Tortugas experiment. The number of recoveries of marked shrimp is related to fishing effort. Estimates of fishing and natural mortality can be calculated for each of the three groups when we identify the fishing intensity applicable to each.

The movement of marked shrimp appeared to be slow and northwesterly from the release sites. During the second month of the experiment (30 to 59 days at large), 93 percent of marked shrimp recovered had moved less than 20 miles; and during the third month, 88 percent were taken within 20 miles of the release areas. We can more accurately assess the rates of movement after we analyze the experimental data.

Growth data obtained from the group of small shrimp released on the eastern edge of the fishing grounds showed a difference in the growth of male and female shrimp. During

Table 6.--Descriptive data pertaining to groups of marked shrimp released and recaptured on the Tortugas fishing grounds, February to April 1965

Study purpose and group	Shrimp size	Primary stain	Secondary stain	Shrimp released	Shrimp recaptured by mid-April
	Inch			Number	Number
Mortality:					
Group 1................	4.5-5.8	Green.......	Arc yellow..	3,107	1,786
Do. 2................	4.5-5.8	.....do.....	Neon red....	2,960	1,828
Do. 3................	4.5-5.8	.....do.....	Saturn: yellow....	3,013	1,589
Growth:					
Group 4................	3.8-4.1	Blue........	None........	2,475	733

the first 2 mo. after release, the average length of male shrimp increased by about 1-1/4 in., whereas the average length of females increased by about 1-3/4 in.

Although we have not made a final analysis of information from this experiment, it appears at present that the data can be used to determine the size at which Tortugas pink shrimp should be harvested.

Charles E. Knight, Project Leader

SIZE COMPOSITION OF COMMERCIAL SHRIMP LANDINGS

Reliable information about harvests is necessary to manage any fishery properly. The information we need includes total weights or numbers caught, size composition of the catch, fishing locations, methods of capture, and amount of fishing effort expended. Information of this nature on commercial shrimp harvests from the Gulf of Mexico is obtained directly from the shrimp industry and is reported monthly in the Bureau of Commercial Fisheries publication "Gulf Coast Shrimp Data."

Because the industry uses two different means for measuring the size composition of landings, the comparability of these methods must be determined. Shrimp unloaded at commercial shrimp houses are purchased from fishermen on the basis of the number of headless shrimp per pound, i.e., 21 to 25, 26 to 30, etc. The size of shrimp in a landing is determined by the box-grading or machine-grading methods. Box grading is accomplished by taking several 5-lb. samples of shrimp as they are unloaded. The average number of shrimp per pound in these samples determines the size category assigned to the landing. A box-graded landing is often assigned to one or two size categories when, actually, it consists of shrimp of a large range of sizes. Machine grading is the mechanical sorting of a landing into several size categories.

To determine the reliability of size composition data from the two methods of grading, we selected and measured samples of shrimp from landings at a number of ports. At shrimp houses using the box-grading method we measured lengths as the shrimp passed along the conveyor belt between a vessel and the house (fig. 17). Samples of shrimp from machine-graded landings were measured after grading. The length measurements were later converted to number of shrimp per pound for comparison with the graded-size information.

Figure 18 compares the count size of sampled shrimp with the reported size categories obtained from the box and machine methods of grading. Actual size composition of the box-graded shrimp has a much greater range than that implied by the reported size

Figure 17.--Measuring shrimp from cnnveyor belt.

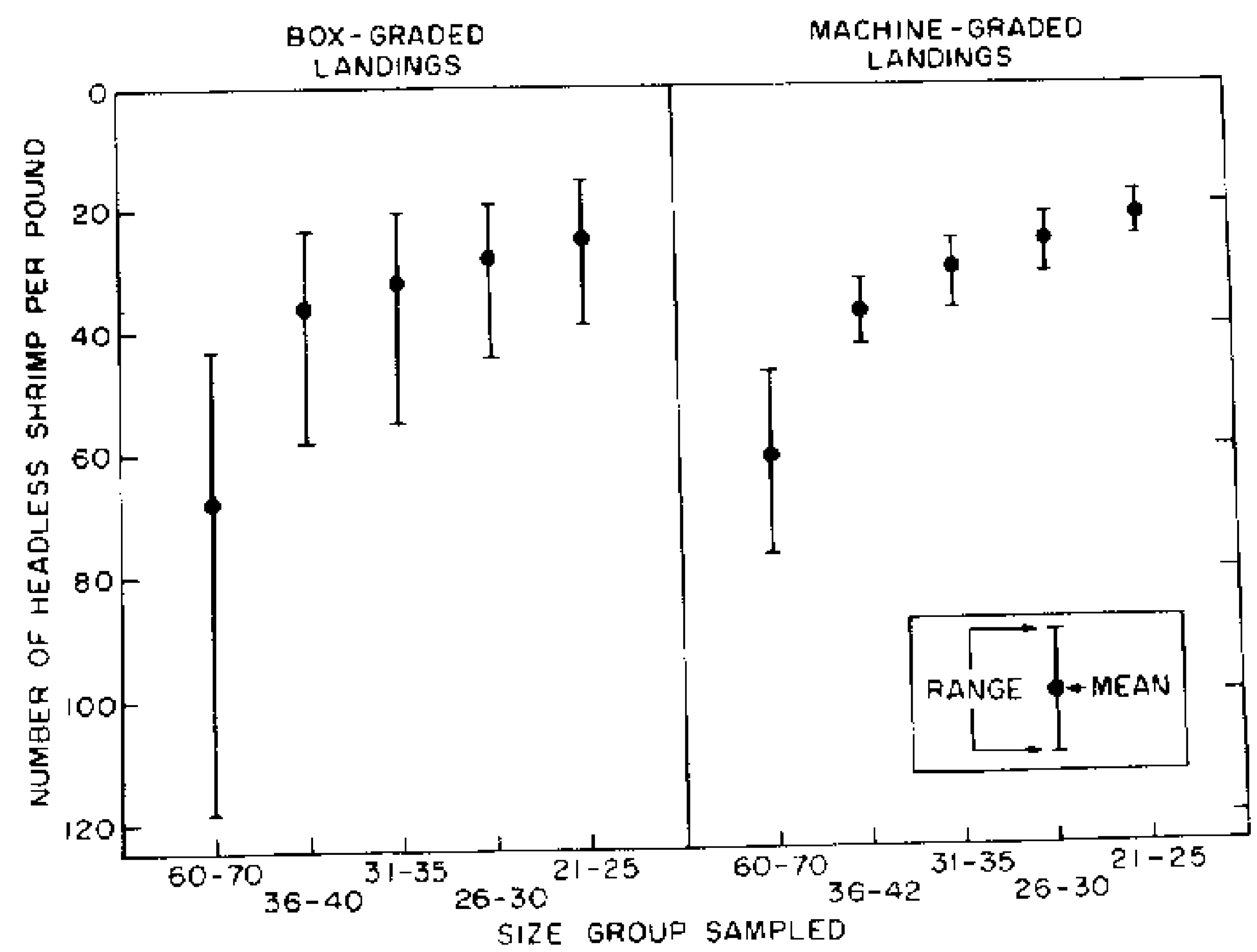

Figure 18.--A comparison of the size composition of shrimp from box- and machine-graded landings. Circles represent average size, and vertical lines indicate the range in which two-thirds of the measured shrimp fell.

groups. The size range for the machine-graded shrimp is considerably smaller, but overlapping of adjacent size groups occurs.

In the examples shown, the average count size of the measured shrimp usually fell within the size categories reported by the shrimp house. In some box-graded samples (not illustrated) the average count size fell well outside the reported size categories and a false picture of shrimp sizes was obtained. Machine grading depicted more accurately the true sizes of shrimp in landings.

Because of the large range of sizes in box-graded landings, we must characterize better the size of the shrimp landed at certain ports. Information from future sampling should enable us to adjust the reported size data for use in population studies.

James P. Clugston, Project Leader

SHRIMP POPULATION STUDIES

The question of whether or not more stringent conservation measures would increase shrimp abundance has given rise to controversy among some segments of the shrimp industry. Proponents of restrictive laws contend that overfishing and, especially, the harvesting of small shrimp have caused a decline in landings. On the other hand, fishermen and processors who supply the demand for small shrimp argue against such legislation. Little evidence has been brought forth to date to support either side. This report illustrates that present harvesting practices probably have little real effect on the abundance or long-term welfare of shrimp stocks.

Concern about shrimp resources becomes especially widespread during years of poor harvests. Concern was great in 1957 and 1961 when the Louisiana white shrimp crop failed to live up to expectations, and in 1961 and 1962 when catches of brown shrimp were poor from Louisiana and Texas waters. Attention has also focused on the Tortugas pink shrimp grounds off the southwestern coast of Florida where some groups believe the fishery is endangered because fishermen catch too many small shrimp.

Landing data gathered from various shrimp fisheries in the Gulf provide valuable information that can be used to gain insight into the causes of fluctuations in shrimp abundance. Detailed landing statistics on commercial shrimp have been collected for all areas of the Gulf since January 1956. Landing data collected before that time often are not strictly comparable because of variations in collecting and recording practices. An exception may be the landing data from the Tortugas grounds which, fortunately, are available for most of the years since the fishery began in 1950. No marked changes or trends in the annual landings from the Tortugas grounds have occurred during this 14-yr. period (fig. 19). Years of better than average or poorer than average harvests are evident, but occur with no particular regularity. Likewise, the sizes of the shrimp landed from the Tortugas grounds have changed little during recent years. (See table 7.) These data indicate that neither intensive fishing nor harvesting small shrimp has had a significant effect on the Tortugas pink shrimp population. The relative stability of this fishery is of particular interest because, with the exception of brief periods, no laws restricting the catch of shrimp have been enforced.

Table 7.--Comparison of the sizes of pink shrimp landed from the Tortugas grounds during recent and past years

Count category (Headless shrimp/ pound)	Total landings	
	1963-64	1956-64 (average)
Number	Percent	Percent
15-20	2.1	2.8
21-25	9.0	9.6
26-30	9.6	10.6
31-40	22.2	22.3
41-50	21.9	20.9
51-67	19.9	18.4
68+	15.3	15.4
Total	100.0	100.0

Landing data on Louisiana white shrimp and Texas brown shrimp (fig. 20) reveal the comparatively brief seasons and marked annual differences in shrimp abundance that characterize these fisheries. In contrast to the Tortugas pink shrimp stock, which is fished heavily for almost 9 mo. of the year, the white and brown shrimp populations support intensive fishing for only a 4- to 6-mo. period. This difference in length of fishing seasons stems from the fact that large numbers of young pink shrimp move onto the Tortugas grounds twice each year, during the spring and fall, whereas white and brown shrimp stocks are replenished once a year. The year-to-year differences in the abundance and catch of white and brown shrimp are caused by annaul variations in the survival of larval shrimp. Similar variations occur in the survival of young pink shrimp but have less noticeable effects on landings because shrimp from more than one brood are commonly on the Tortugas grounds at the same time.

A clue to the type of factors that cause poor survival among larval shrimp has become apparent from patterns in landing data. Comparisons of shrimp catch per unit of fishing effort (pounds per hour) along the

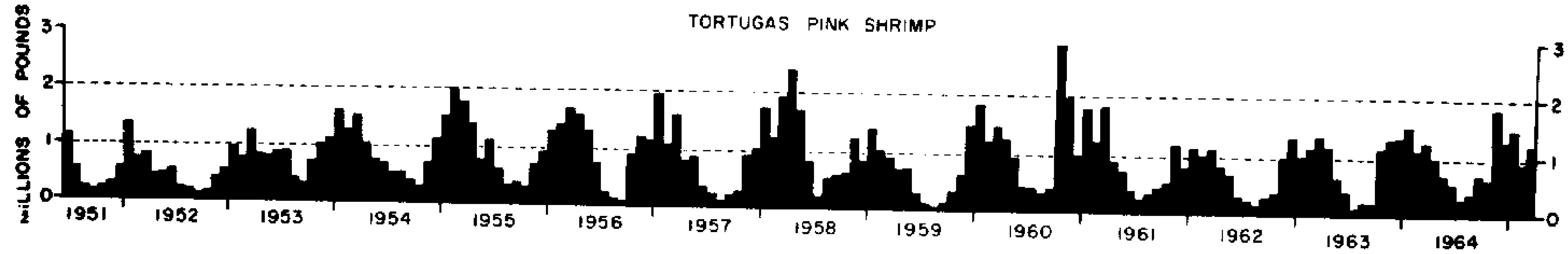

Figure 19.--Monthly landings from the Tortugas pink shrimp fishery, June 1951 to March 1965.

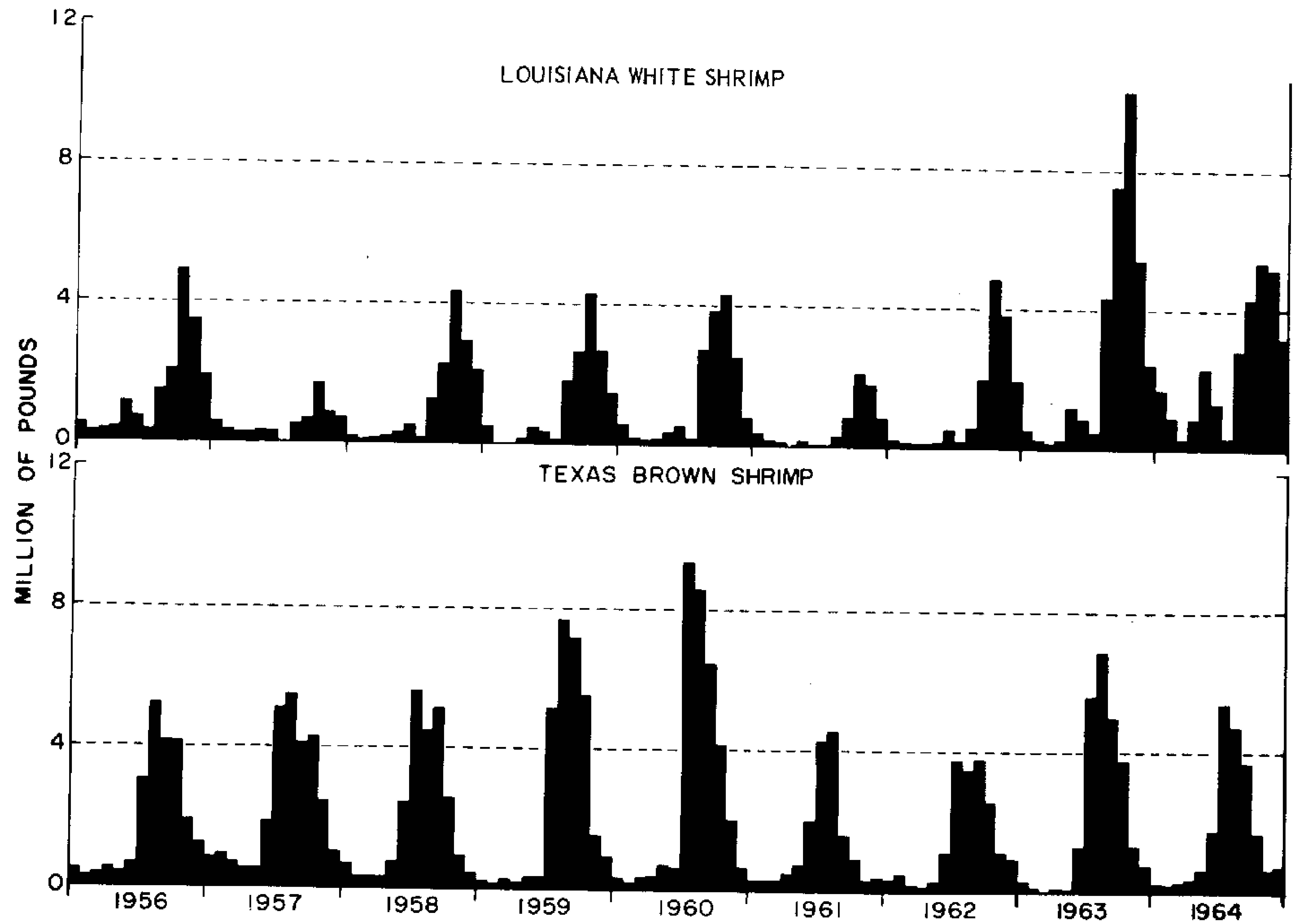

Figure 20.--Monthly landings of white shrimp from Louisiana waters and brown shrimp from Texas waters, 1956-64.

Gulf coast from Mobile Bay to the United States-Mexican border indicate that the relative abundance of brown shrimp during a given period is about the same throughout this area. In years of high abundance, brown shrimp are plentiful over the entire area, and during years of low abundance, brown shrimp are scarce over the area. The factors responsible for such widespread fluctuations in abundance are unknown, but are assumed to be linked to oceanographic conditions. Taking this type of comparison one step further, figure 21 illustrates a relation during 1958-64 between the abundance of brown shrimp along the Texas coast and pink shrimp on the Tortugas grounds. If the levels of abundance of shrimp in these two widely separated areas follow similar trends in the future, we will have stronger evidence that widespread oceanographic conditions are responsible for much of the difference between years of good and poor harvests.

Fluctuations in abundance of white shrimp do not correspond to those of pink or brown shrimp, possibly because the former are spawned in near-shore Gulf waters where the effects of oceanographic factors are confounded by influences of land origin. Like the brown shrimp stocks, however, population levels of

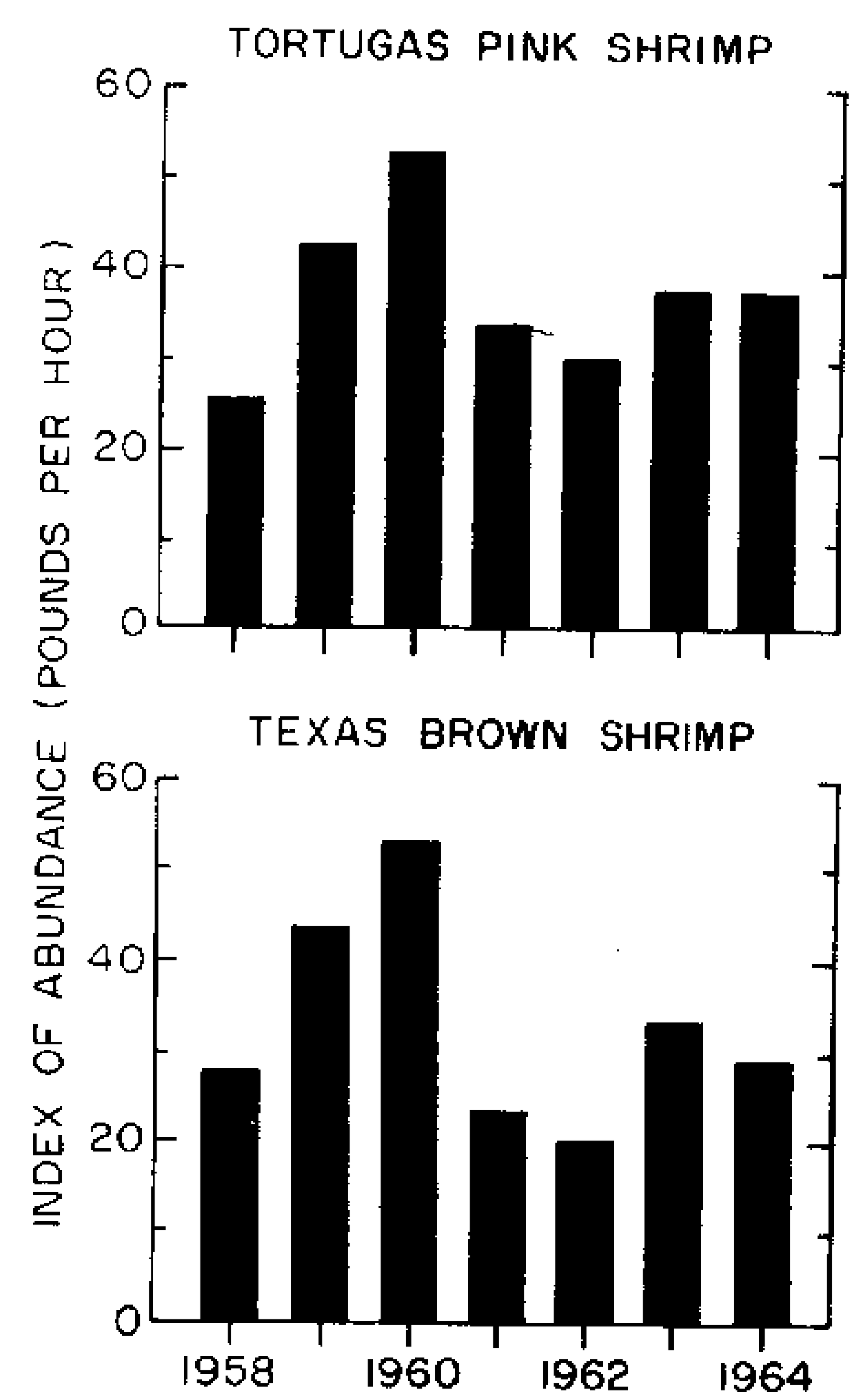

Figure 21.--Comparative abundance of Tortugas pink and Texas brown shrimp, 1958-64.

white shrimp are similar during a given period over broad geographic areas. No single factor has been shown to cause the yearly variations in white shrimp abundance, but some evidence suggests that changes in the salinity of shallow coastal waters may play an important role. A negative relation between the August to December catch of white shrimp from Louisiana and the velocity of spring water flows in the Mississippi River suggests that large harvests of white shrimp occur in those years when the spring runoff is below normal. Salinity itself may not have a direct effect on the survival of the larval white shrimp, but it appears that some associated factor is involved.

Even though the specific causes of fluctuations in shrimp abundance have not been identified, it is becoming apparent that they result from environmental changes that occur over large parts of the Gulf. Otherwise, measures of abundance of brown or white shrimp would not be similar over wide geographic areas nor would a correspondence be found between population levels of Texas brown and Florida pink shrimp. Similar densities of shrimp over broad and widely separated areas are also interpreted to mean that other factors affecting shrimp abundance, such as differences in fishing intensities and in laws governing harvesting practices, have slight influence on population levels.

Richard J. Berry, Project Leader

ABUNDANCE OF POSTLARVAL AND JUVENILE SHRIMP

Past success in predicting abundance of adult brown shrimp from densities of postlarvae and juveniles in estuarine nursery areas has led us to expand our sampling program. We are collecting postlarval shrimp routinely from Aransas Pass, Galveston, Gilchrist, and Sabine Pass, Tex. Additionally, our study of juvenile shrimp collected from the commercial bait-shrimp fishery of Galveston Bay has been supplemented by our investigations of bait-shrimp fisheries in Aransas Bay and in lower Laguna Madre. A study of the growth of juvenile brown and white shrimp in Galveston Bay has also been started to determine how year-to-year differences in shrimp growth may be associated with changes in abundance.

Postlarval Shrimp

The abundance of postlarval brown shrimp in collections from the entrance to Galveston Bay during March and April 1965 was similar to that for the corresponding period in 1964; however, other factors suggest that the offshore harvest of brown shrimp may be somewhat greater in 1965. Postlarval brown shrimp were caught at all sampling stations during the winter of 1964-65, in contrast to their near absence in samples of past winters. The presence of postlarvae may have been related to above-average water temperatures. We do not know whether these postlarvae survived short intervals of cold temperatures during February and March. Also, measures of abundance of juvenile brown shrimp, in terms of pounds caught per hour of fishing, were slightly higher this year than in 1964. All factors considered, the 1965 catch of brown shrimp should exceed that of 1964.

We made special studies this spring of factors influencing the movement of postlarvae into nursery areas. Two 72-hr. studies were performed at Rollover Pass, Tex., on March 22 to 25 and April 26 to 29. Samples were collected hourly over three complete tide cycles with a 1/2-m. (19.7-in.) plankton net fitted with a flowmeter. A V-Series Ice Meter, which records current velocity in feet per second, was also used. Current velocities during flood tides at Rollover Pass were found to be double those recorded during ebb tides. Apparently, a major peak of postlarval brown shrimp was moving into the bay at the time of the first study when 32,940 were caught. Only 3,310 brown and 840 white shrimp postlarvae were taken during the second survey. To some degree, postlarvae moved in both directions with the current, but greater numbers were caught on flood tides. We learned of no relation between time of day and numbers of postlarvae caught.

A similar 72-hr. study was made on Galveston Island beach during April 5 to 7. Hourly tows were made with a 5-ft., hand-drawn beam trawl. The net was carried out 100 ft. into the surf, set, and pulled back to shore. Dye was released in the sample area to determine surface current movement. Fluctuations in numbers of postlarvae caught at this location may be related to time of day, because 68 percent of the 13,200 brown shrimp postlarvae were taken at night. Additional studies are needed, however, before we can draw definite conclusions.

Juvenile Shrimp

We began a study of the growth of juvenile shrimp in Swan Lake, a shallow nursery area adjoining the lower part of Galveston Bay. Collections were made with a 10-ft. otter trawl fitted with a fine-mesh cover over the cod end. The size distributions of shrimp caught from April 1 through June 17 are shown in figure 22. Postlarval brown shrimp were present in considerable numbers by April 1, but little growth was evident before April 15. Two groups of

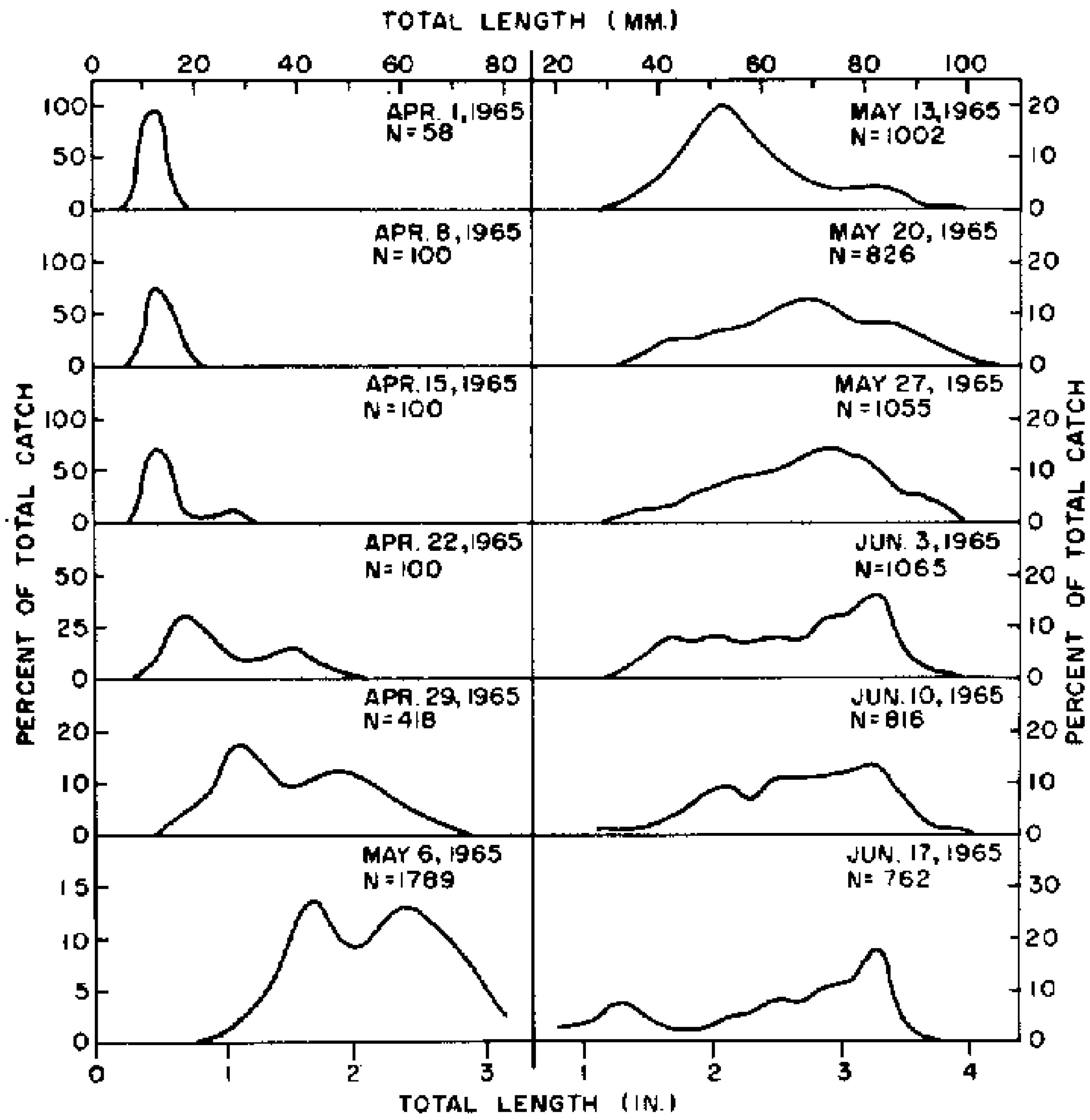

Figure 22.--Length-frequency curves for brown shrimp from Swan Lake (Galveston Bay), April 1 through June 17, 1965.

juvenile brown shrimp were present for the following 3 wk., and then the larger group moved from the lake presumably to Galveston Bay. During this period, the weekly growth increment of each group was about 10 mm. (3/8 in.). Juvenile white shrimp were caught first on June 10 and dominated catches by June 24.

To obtain information on species composition, we began preliminary investigations of bait-shrimp fisheries in Aransas Bay and in lower Laguna Madre. Samples of bait-size shrimp are collected each week from these areas, frozen, and forwarded to the Galveston Laboratory. Variation in species composition as revealed by samples from three bay systems is shown in table 8. Bait-shrimp catches from Galveston Bay are predominately white or brown shrimp, whereas those from Aransas Pass and lower Laguna Madre show a high incidence of pink shrimp. These figures do not necessarily reflect the relative production of the three species of shrimp, however, since each species spends a different proportion of its life in estuarine waters.

Kenneth N. Baxter, Project Leader

Table 8.--Species composition (percent) of bait shrimp from the major bay systems along the Texas coast[1]

Date	Galveston Bay			Aransas Bay			Lower Laguna Madre		
	Brown	White	Pink	Brown	White	Pink	Brown	White	Pink
1964	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
August..........	4	96	00	8	91	1	11	46	43
September.......	9	91	0	8	79	13	3	0	97
October.........	7	93	0	23	67	10	19	36	45
November........	3	96	1	42	33	25	0	1	99
December........	1	99	0	2	98	0	1	25	[1] 73
1965									
January.........	0	98	[1] 0	5	70	[1] 24	3	26	71
February........	4	90	[1] 1	16	48	[1] 28	1	2	[1] 96
March...........	0	98	2	14	36	[1] 48	2	1	[1] 96
April...........	4	68	28	1	22	[1] 76	17	1	[1] 81
May.............	84	11	5	72	0	28	66	0	34
June............	98	1	1	95	0	5	80	0	[1] 19

[1] When percentages do not total 100, the remainder is composed of Trachypeneus species, Xiphopeneus krøyeri, Sicyonia dorsalis, or Macrobrachium spp.

STUDIES OF POSTLARVAL SHRIMP IN VERMILION BAY, LA.

The University of Southwestern Louisiana has conducted sampling to investigate fluctuations in the seasonal abundance of postlarval shrimp in Vermilion Bay since February 1963. Samples are collected each week with a hand-drawn beam trawl that is towed over a measured distance near the shoreline. Three sampling stations are located within the bay, and two others are near an entrance to the bay. Results obtained thus far indicate that the movements of postlarval brown and white shrimp into Vermilion Bay take place at about the same calendar time as in the Galveston Bay area. Brown shrimp postlarvae predominate in samples taken during the early spring, and postlarval white shrimp are more abundant beginning in June. The relative numbers of postlarvae vary considerably among the five stations, and it is apparent that some sampling locations do not provide a reliable indication of postlarval abundance. We anticipate that a relation can be found between the abundance of postlarvae at one or two stations and the subsequent production of commercial shrimp.

We made a special study to determine the causes of fluctuations in the number of postlarvae caught over a short time interval near the entrance to Vermilion Bay from August 30 to September 3, 1964. We obtained duplicate samples of postlarvae at 2-hr. intervals throughout the 4-day period. The results of this study indicate that the number of postlarvae in a sample is directly related to the tidal stage (fig.23). This knowledge makes it apparent that future collections from this location should be made at the same stage of the tide each week if they are to reflect the abundance of postlarvae.

Charles W. Caillouet, Jr., Project Leader

University of Southwestern Louisiana
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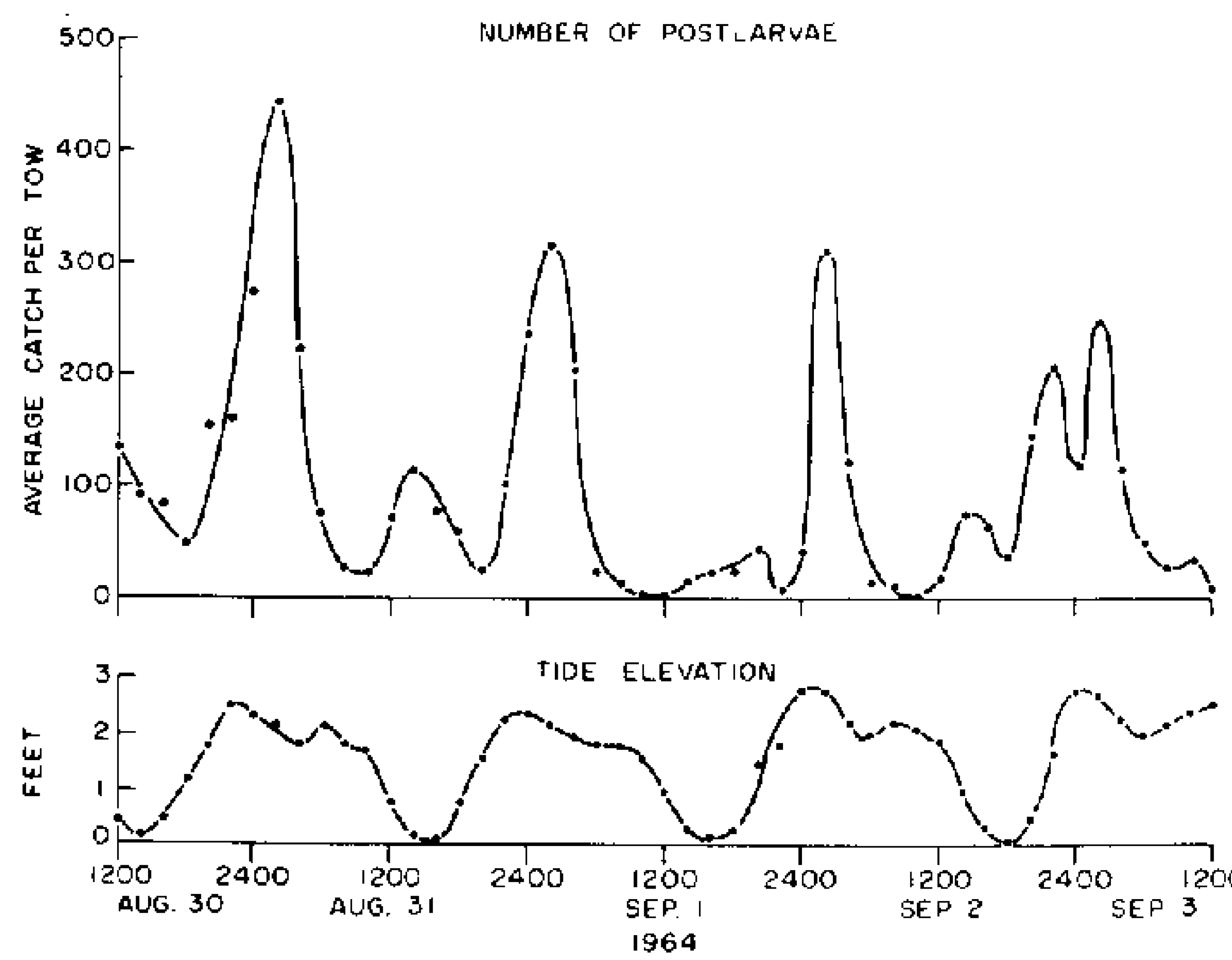


Figure 23.--Fluctuations in the catch of postlarval shrimp and in tide elevation near Marsh Island, La., August-September 1964.

ESTUARINE PROGRAM

The Gulf of Mexico contributes almost one-third of the total U.S. commercial fishery production. Significantly, the bulk of this harvest is comprised of species that depend on estuaries. Unfortunately, demands on Gulf coast water resources are rapidly causing alteration of most and destruction of many estuaries. Our program of estuarine research studies these valuable coastal waters so that we may develop a better understanding of the mutual relations of the estuary-dependent animals and their environment. The information from this research provides the basis to assure that coastal fishery resources receive adequate consideration in plans to develop upland water supplies and estuarine basins.

We had previously reported that we could describe with reasonable accuracy the seasonal patterns of distribution, size composition, and relative abundance of many commercially important species in the Galveston estuary. Now we can also describe in considerable detail many of this estuary's hydrographic and hydrological characteristics. Thus, we are assessing the type of zone most suited for each major species (and the zone to which each developmental stage is best adapted) and, in turn, we hope to determine the amount of fresh water required to maintain such zones for the maximum benefit of estuary-dependent fishery resources.

Even though the salinity zonation is being studied first because of its direct and measurable relation with river discharge, we are also, in a similar manner, assessing other factors--such as temperature, depth, bottom sediment types, primary productivity, pollutants, nutrient levels, and geographic location. This phase of study is well underway.

Our work in assessing water development projects continues to increase and become more complex. The economic potential of fishery resources developed during our preliminary evaluation of the Texas Basins Project (U.S. Fish and Wildlife Circular No. 230) now permits us to make monetary assessments of many projects that would directly modify or destroy an estuary. We can estimate, for example, the average value per acre of estuarine nursery habitat as well as the value of a unit volume of tributary fresh water. Knowledge of these values is a very useful tool which has already served well in the evaluation of several projects. Research, however, must continue to provide more knowledge so we can improve these interim figures and thus better defend our fishery resources during the struggle to develop the water resources and estuarine basins of the Gulf coast.

The Galveston estuary usually receives sufficient fresh water to provide a wide range of environmental conditions; consequently, it accommodates at high levels many different estuary-dependent species. Among them are large numbers of shrimp that contribute significantly to the catch in the Gulf of Mexico.

Many species, including the white and brown shrimp, travel extensively while undergoing development in the estuary and, so, occupy several different hydrological and hydrographic zones over a relatively short period. Perhaps their requirements or preferences change from one developmental stage to the next. For example, in the Galveston estuary during 1963 and 1964 the smaller juvenile brown shrimp were concentrated in those parts of the estuary where salinity was less than 10 p.p.t. As they grew, however, they occupied zones of higher salinity. They did not use extensively those portions of the estuary where salinity exceeded 25 p.p.t. We developed this information by measuring more than 40,000 shrimp collected in 1,655 trawl samples (fig. 24).

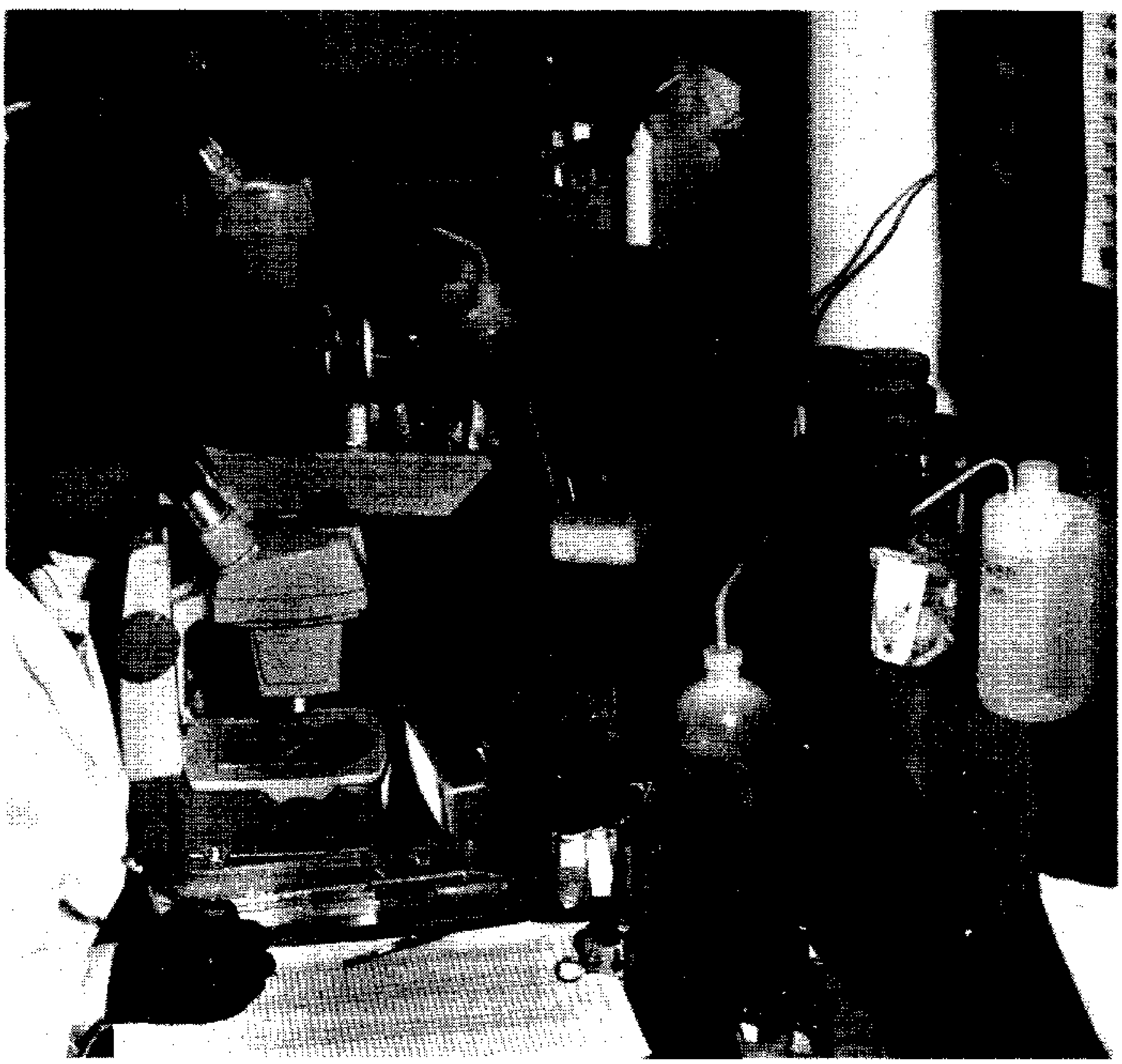


Figure 24.--Project personnel in our new laboratory facility identifying and measuring small shrimp collected from Galveston estuary.

Generally, an estuary has a wide range of environmental conditions, but the extent or size of a particular zone may be a factor controlling a species' success or failure.

Most of the data collected during 1963 and 1964 have been entered on about 250,000 cards for automatic data processing (ADP). Our acquisition of a key punch and sorter has speeded this work considerably (fig. 25).

During fiscal year 1965 we installed radio equipment, which enables us to communicate directly with our vessels in the field (fig. 26).

We continue to enjoy excellent cooperation in the exchange of data and services with many Federal, state, and private organizations. Most recently, we provided assistance to the National Aeronautics and Space Administration by analyzing sediment samples from several of their test areas.

Charles R. Chapman, Program Leader

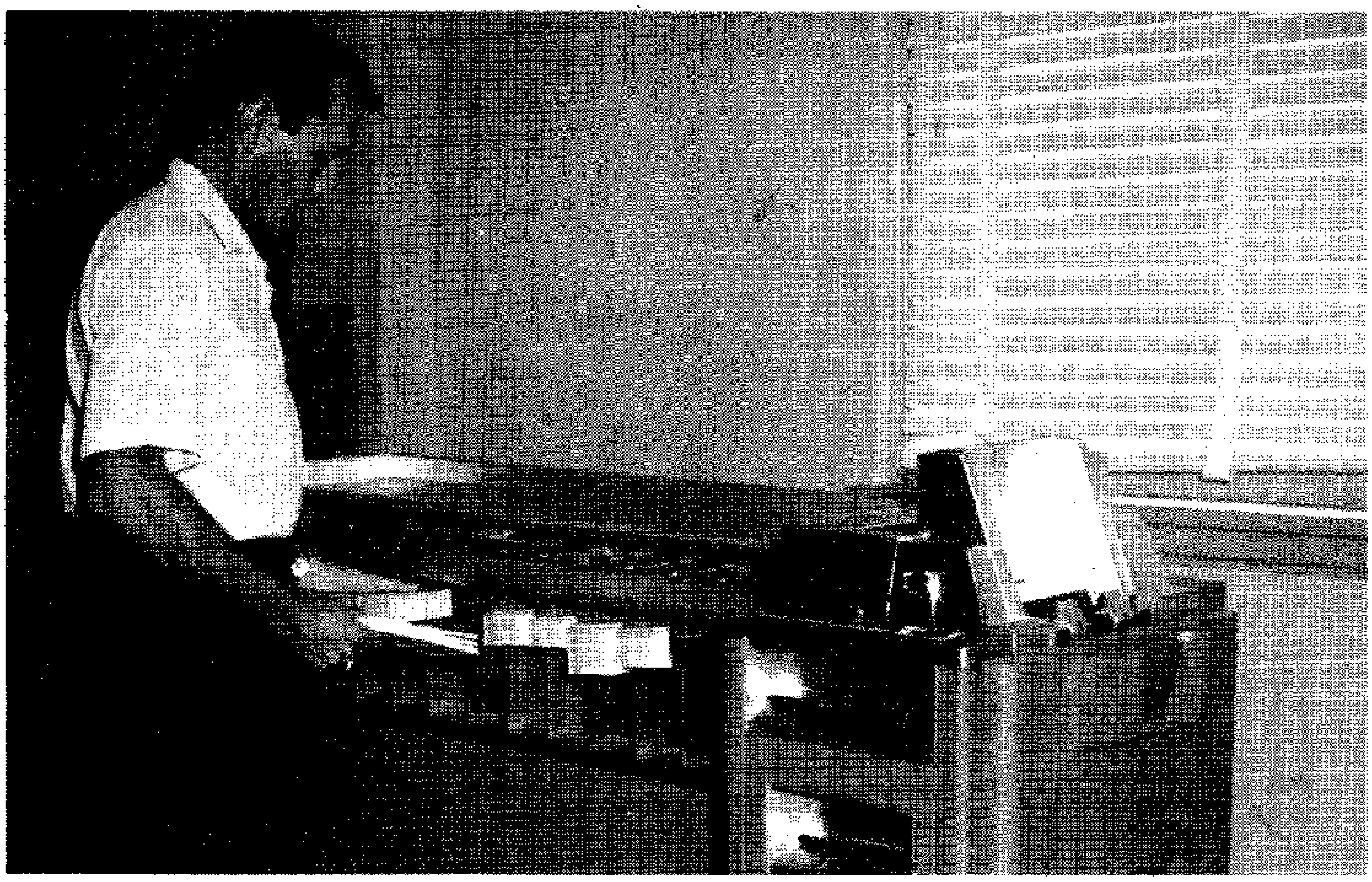
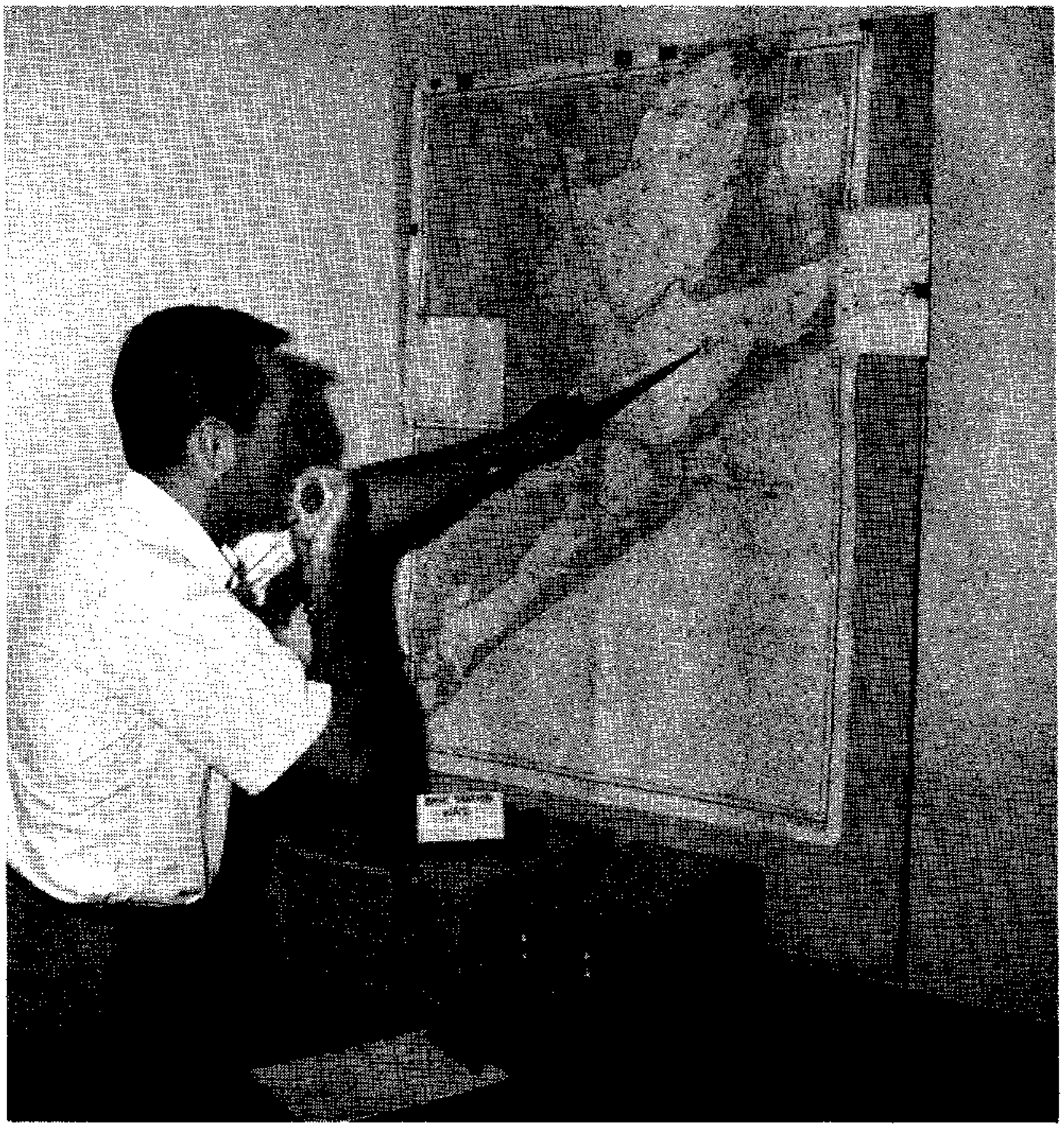


Figure 25.--Sorting ADP Cards for computer analysis. All data collected in the estuary during 1963 and 1964 have been transcribed to more than 250,000 cards to facilitate their storage, retrieval, tabulation, and analysis.



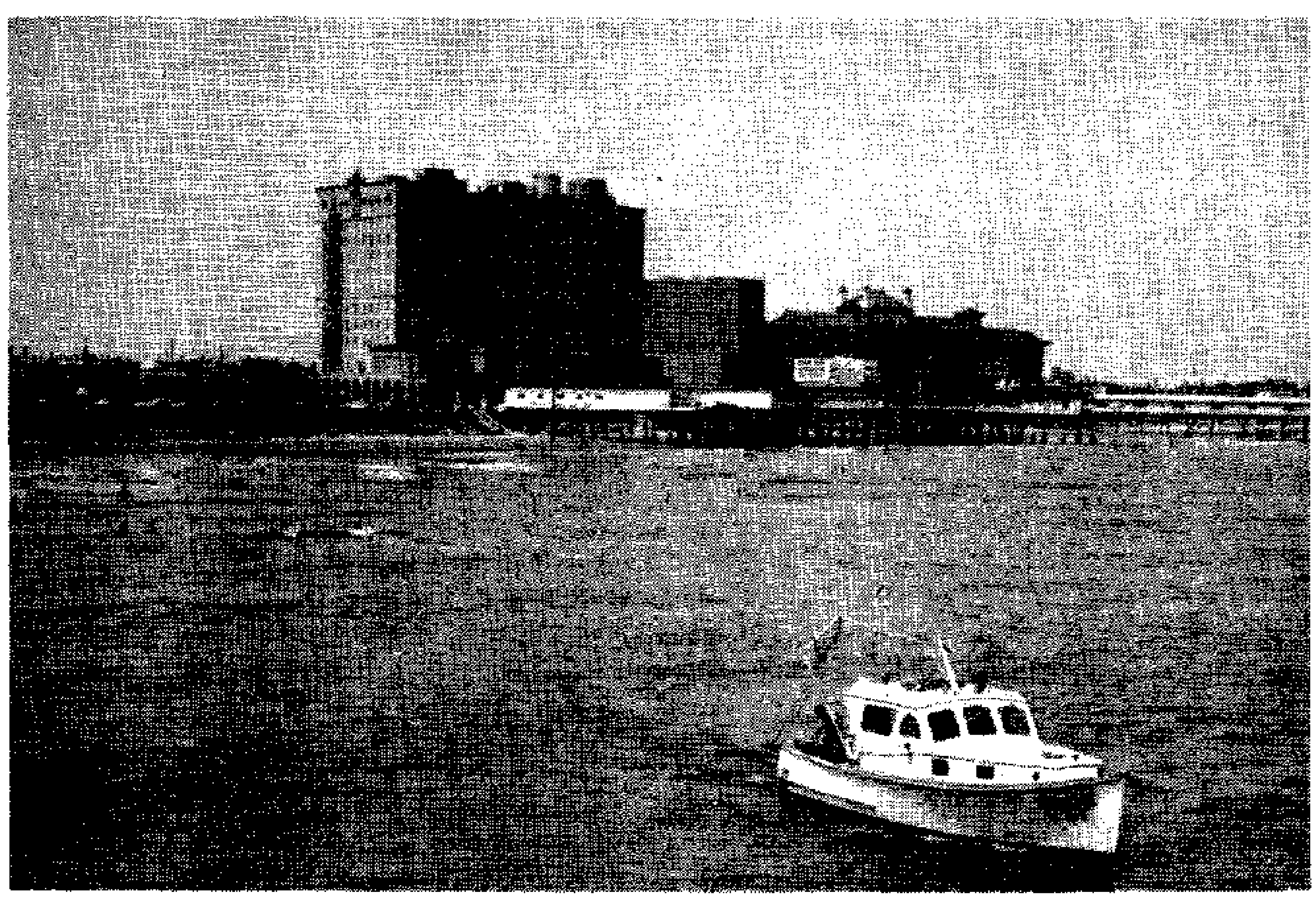


Figure 26.--Project Leader directing field work from laboratory. Radio communications between laboratory and vessels provide for more efficient use of manpower and equipment.

ECOLOGY OF WESTERN GULF ESTUARIES

A wide range of activities was included in this project during this fiscal year. Hydrological and biological sampling continued throughout the Galveston estuary. Once a month from July through December, we occupied 65 stations within the bays, lagoons, and bayous and 8 stations in the bordering marshes. In January, we began sampling weekly so we could study intensively the postlarval and juvenile brown shrimp when they abound in the estuary. Considerable effort has been devoted, in the past year, to evaluating data collected on postlarval and juvenile brown shrimp during 1963 and 1964. We have analyzed sediment samples from the estuary and have prepared a map depicting the major sediment types. We have also studied the possible relation between the concentration of organic matter in the sediments and the abundance of postlarval and juvenile shrimp. A primary productivity study spanning 1 yr. (July 1964 through June 1965), has been completed; the resulting data are now being analyzed.

Hydrology

Following the normal seasonal pattern, monthly mean water temperature was highest in August 1964 and lowest in January 1965. During 1964-65 winter, waters in the estuary were considerably warmer than in 1962-63 and 1963-64 winters. The lowest value reported this winter was 10.0° C. (50.0° F.) in February and March 1965 as contrasted to a low of 3.5° C. (38.3° F.) in January 1964 and 2.7° C. (36.9° F.) in January 1963. These exceptionally warm conditions were apparently responsible for more animals overwintering in the estuary than have been observed in previous years.

From November 1964 to the end of this fiscal year, salinity has been somewhat lower in the Galveston estuary than during the same period in 1962-63 and 1963-64, and since April, the waters of upper Trinity Bay have been essentially fresh. Biological data from these waters should give us a good picture of how extremely low salinities affect the density and abundance of the animal populations.

Throughout the bay system, the annual seasonal highs for dissolved oxygen were observed during winter and the lows during summer. Monthly mean dissolved oxygen at the bottom (daytime) varied between 16.7 p.p.m. (parts per million) near the mouth of the San Jacinto River in October 1964 during a plankton bloom and 4.9 p.p.m. in the Gulf during July 1964.

During the year, total nitrogen and phosphate levels were consistently highest in the upper estuary and declined Gulfward. Total nitrogen varied from a monthly mean low in July 1964 of 19.1 μg.at./l. (microgram atoms per liter) in the near-shore Gulf of Mexico to a high of 122.2 μg.at./l. near the mouth of the San Jacinto River in December. In July, the highest level of total phosphate (13.36 μg.at./l.) was recorded near the mouth of the San Jacinto River, and the lowest in the near-shore Gulf of Mexico. The area near the mouth of the San Jacinto River receives large amounts of industrial waste and domestic sewage. This pollution load in the waters of the lower estuary and the near-shore Gulf of Mexico is diluted considerably through tidal exchange with the open sea (fig. 27).

Primary Productivity

Although the analysis of the data is not yet complete, preliminary findings indicate that the greatest primary productivity was consistently in the surface water. As light penetration, because of high turbidity, diminished rapidly with depth in the water column, productivity diminished correspondingly. Highest seasonal levels of production in the surface waters were in the summer and winter, whereas the seasonal lows occurred in the fall and spring.

Production throughout the year was highest in the waters of upper Galveston Bay and lowest in lower Galveston Bay. Discharge of sewage and industrial and municipal waste is heaviest in the upper Galveston Bay area, and these waters consistently carry the greatest nutrient load; thus suggesting that nutrients supplied from these sources (pollutants) account in part for the high productivity.

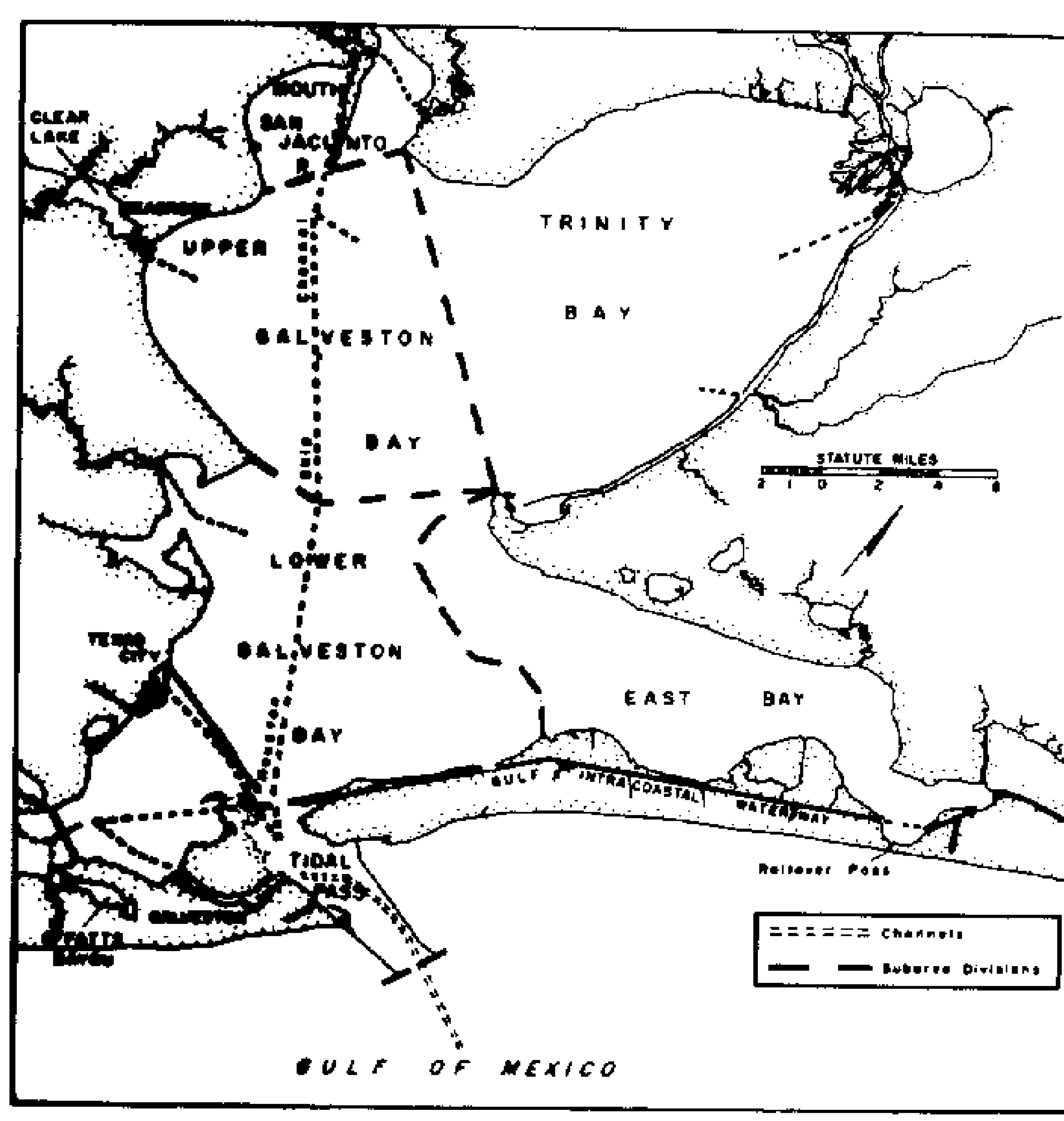


Figure 27.--Map of the Galveston Bay estuarine system.

We do not know at what level the concentration of these wastes becomes detrimental to the primary producers.

Fresh-Water Discharge and Salinity

Such natural factors as wind, rainfall, evaporation, tidal intrusion, fresh-water discharge, and basin size and configuration influence the salinity regimen of an estuarine system. Of these factors, fresh-water discharge is perhaps the most significant because it measurably dilutes the salt waters of the sea to form the estuarine "buffer zone" or ecotone and transports large amounts of nutrients derived from land drainage to the estuary.

The Galveston estuary possesses a typical salinity gradient; salinity is lowest in the upper bays and increases Gulfward. Because Texas is characterized by periods of drought and excessive rainfall, tributary discharge into this estuary is frequently erratic. This variability is reflected in the salinity gradient and hydrological zonation of the estuary. During periods of high river flow, salinities over much of the estuary are depressed, whereas during drought, salinity becomes high.

Many estuary-dependent species require or prefer different hydrological conditions. Fortunately, even during wet and dry cycles, the salinity gradient in Galveston estuary is characterized by a broad range of conditions that accommodates many species. During drought, however, the high salinity zones may enlarge, so that species that prefer high salinity may occupy more of the estuary. The reverse is also true. Tributary discharge controls, to a large extent, the amount of area comprising a particular salinity zone. Thus, it becomes imperative to describe the type of gradient zonation most suited to the complex of estuarine organisms and to determine the amount of fresh water required to perpetuate the zonation. We must also determine how departure from optimum conditions will affect these resources.

For the Galveston estuary, we based our first efforts to relate river discharge and salinity on records from October 1960 through December 1964 of discharge from the Trinity River, the major source of fresh water. Seasonal and annual variations in river discharge were considerable. Generally, 1961 and 1962 were years of high tributary discharge, whereas river flow was considerably reduced in 1963 and 1964. During the wet year of 1961, salinity for the entire estuary averaged about 6.5 p.p.t., whereas during the dryer year of 1963 it averaged 18.5 p.p.t. During the 4-yr. period the average salinity of Trinity Bay, which receives directly the Trinity River discharge, was about 10.0 p.p.t. Salinity of lower Galveston Bay during this period averaged more than 22.0 p.p.t. Each of the subbays of the estuary is influenced differently by tributary fresh water (fig. 28).

Seasonal differences in salinity are also evident. River flow is usually highest during winter and spring. River water moving through the estuary toward the Gulf in winter is aided by the prevailing northerly winds and seasonally low tides. Under these conditions, fresh waters from the Trinity River can pass through the estuary in less than 1 mo. During the summer and fall, when river discharge is usually lowest, dispersion of fresh water is usually hindered by prevailing southerly winds and higher tides. Thus, 1-1/2 to 2 mo. may elapse before fresh water from Trinity River is completely dispersed throughout the estuary.

A much more sophisticated analysis of these data will be required to develop suitable mathematical models that will enable us to predict how specific volumes of tributary fresh water will affect the gradient and zonation of salinity in the estuary.

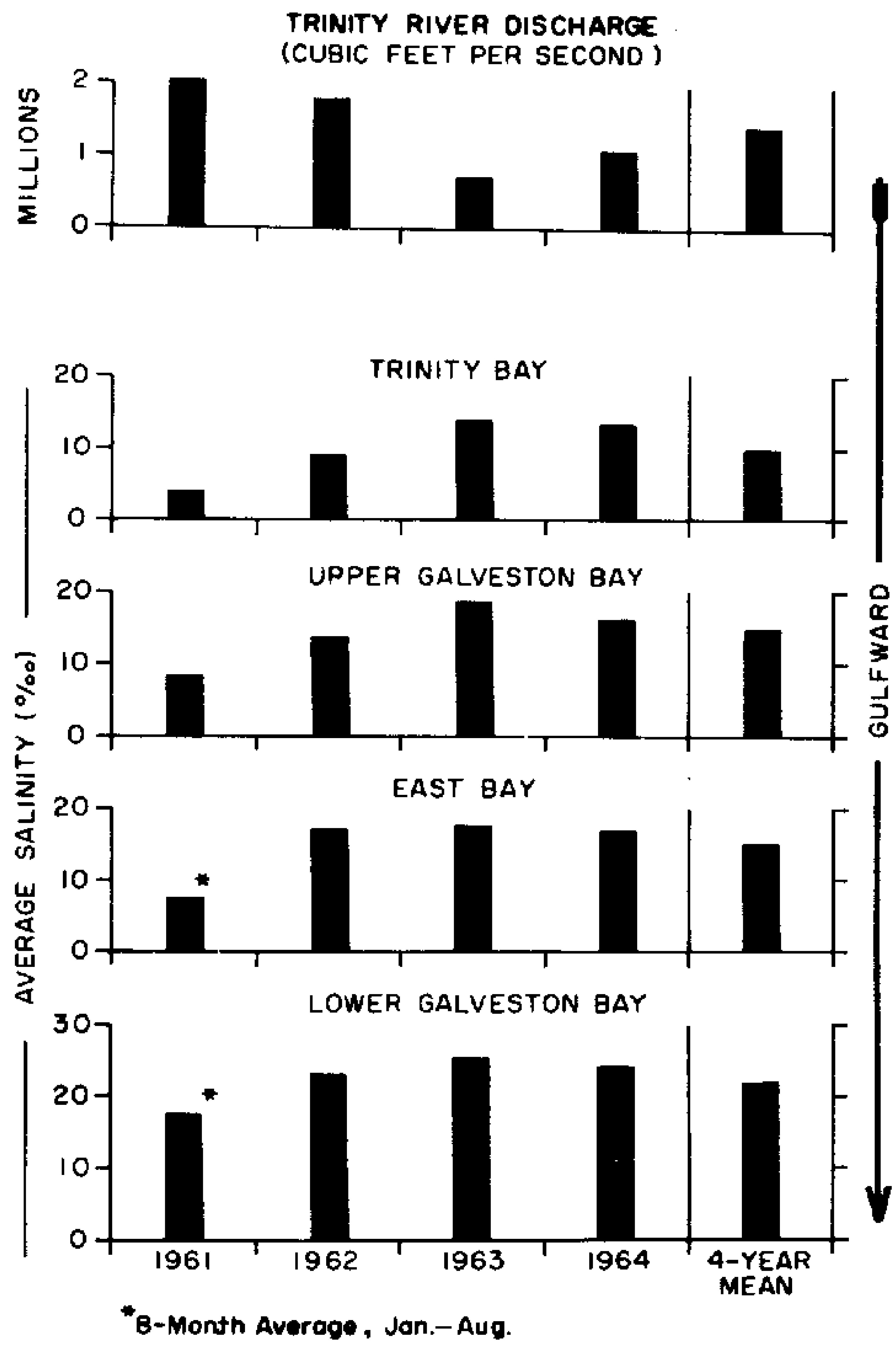


Figure 28.--Relation between average annual Trinity River discharge and salinity in the subbays of Galveston etsuary, 1961-64.

Distribution and Density of Juvenile Brown Shrimp

Because the brown shrimp is the most valuable species harvested commercially from Texas coastal waters, we are devoting considerable effort toward study of its inshore life history. Partial evaluation of data collected during 1963 and 1964 permits us to describe this shrimp's distribution and relative abundance within the Galveston estuary. We are still processing data collected since January 1965.

The behavior exhibited by brown shrimp in the estuary was similar in 1963 and 1964. Postlarval brown shrimp, after entering the estuary from the Gulf, migrated toward the upper bays, predominately through the Houston Ship Channel, Intracoastal Waterway, and deeper waters of the open bays. Within 2 wk. they were dispersed throughout the estuary and were concentrating in their primary nursery areas--the peripheral marshes, bayous, and smaller bays (fig. 29). They remained in these protected waters from 2 to 4 wk., growing rapidly, until they developed into juveniles. Thereafter, they began to disperse throughout the estuary before returning to the Gulf. Differences between temperature cycles in 1963 and 1964 during the time of postlarval influx and initial growth suggest that the duration of this phase of the shrimp's life history is regulated in large part by the water temperature.

The dispersion of juveniles throughout the estuary followed a rather distinct pattern. The first juveniles were caught in 1963 during semimonthly trawl sampling in early April in East Bay and Trinity Bay near extensive marshes where postlarvae were concentrated. Within 2 wk. they had dispersed practically throughout the estuary and by late May had begun to return to the Gulf. The same general behavior was evident in 1964 even though trawl sampling was conducted only once each month. During May, when juveniles were most abundant and dispersed throughout the estuary, they were concentrated once again in the shore zones near the marshes. Much of the detail of their dispersion, however, was not obtained by the limited monthly sampling. By July of 1963 and 1964, most of the brown shrimp had returned to the Gulf.

Striking differences in the relative abundance of brown shrimp in the Galveston estuary were evident between 1963 and 1964 (fig. 30). Considerably fewer shrimp were caught in 1964, and the subsequent offshore catch was also proportionately lower. This correlation suggests the possibility of estimating future production in the Gulf by determining the density (relative abundance) of the juvenile population harbored in the estuary. Our studies indicate that this method of projection has merit and should be tested over a longer period. Rather intensive sampling would be required in the estuary's shore zones adjacent to the marshes during April, May, and June.

The relation between the density of juvenile brown shrimp and salinity during 1963 and 1964 was distinct. Generally, the smaller

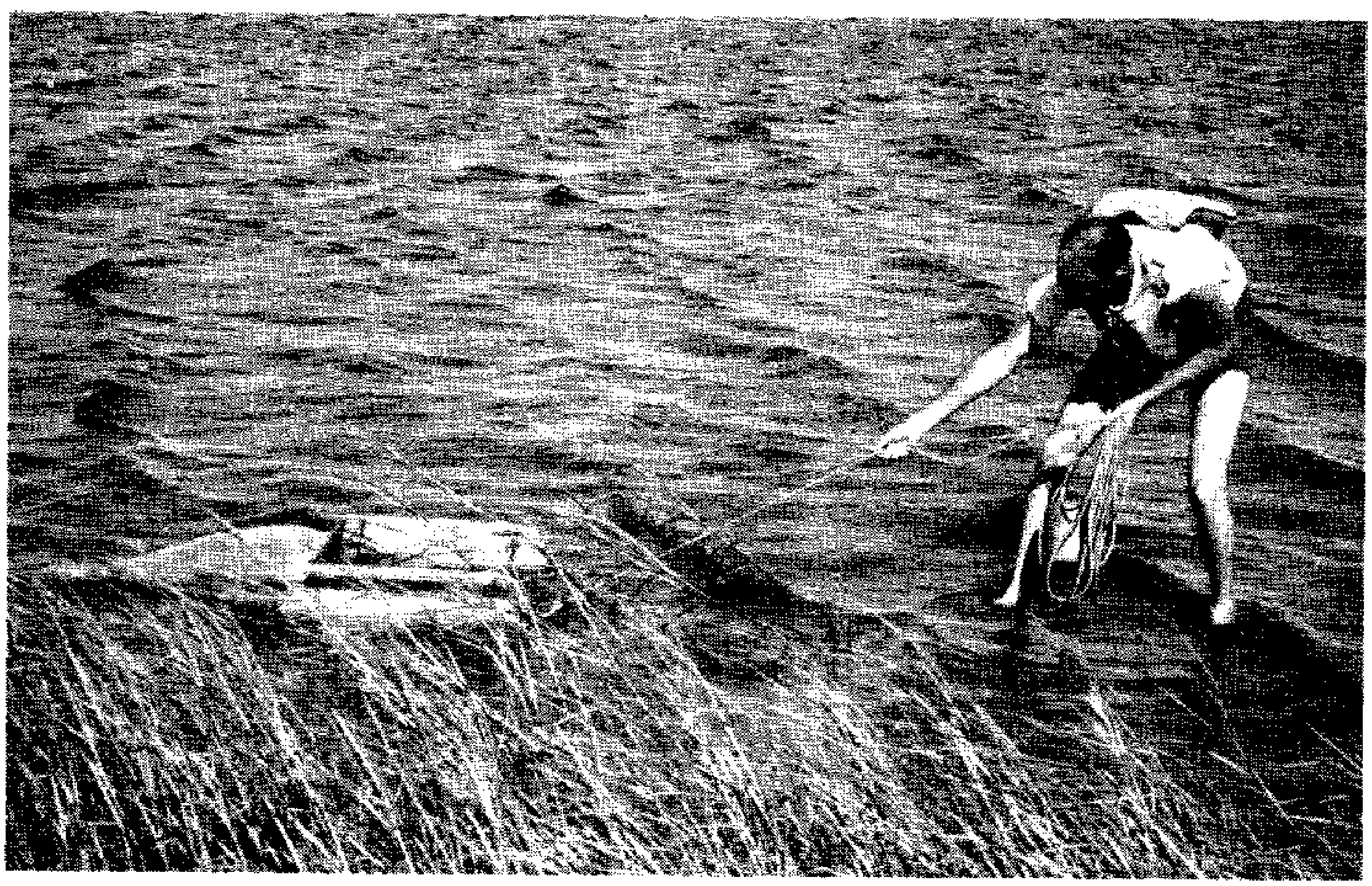


Figure 29.--Sampling in the estuary's peripheral marshes with device developed by project personnel. Such locations provide critical primary nursery areas for small fish and shrimp.

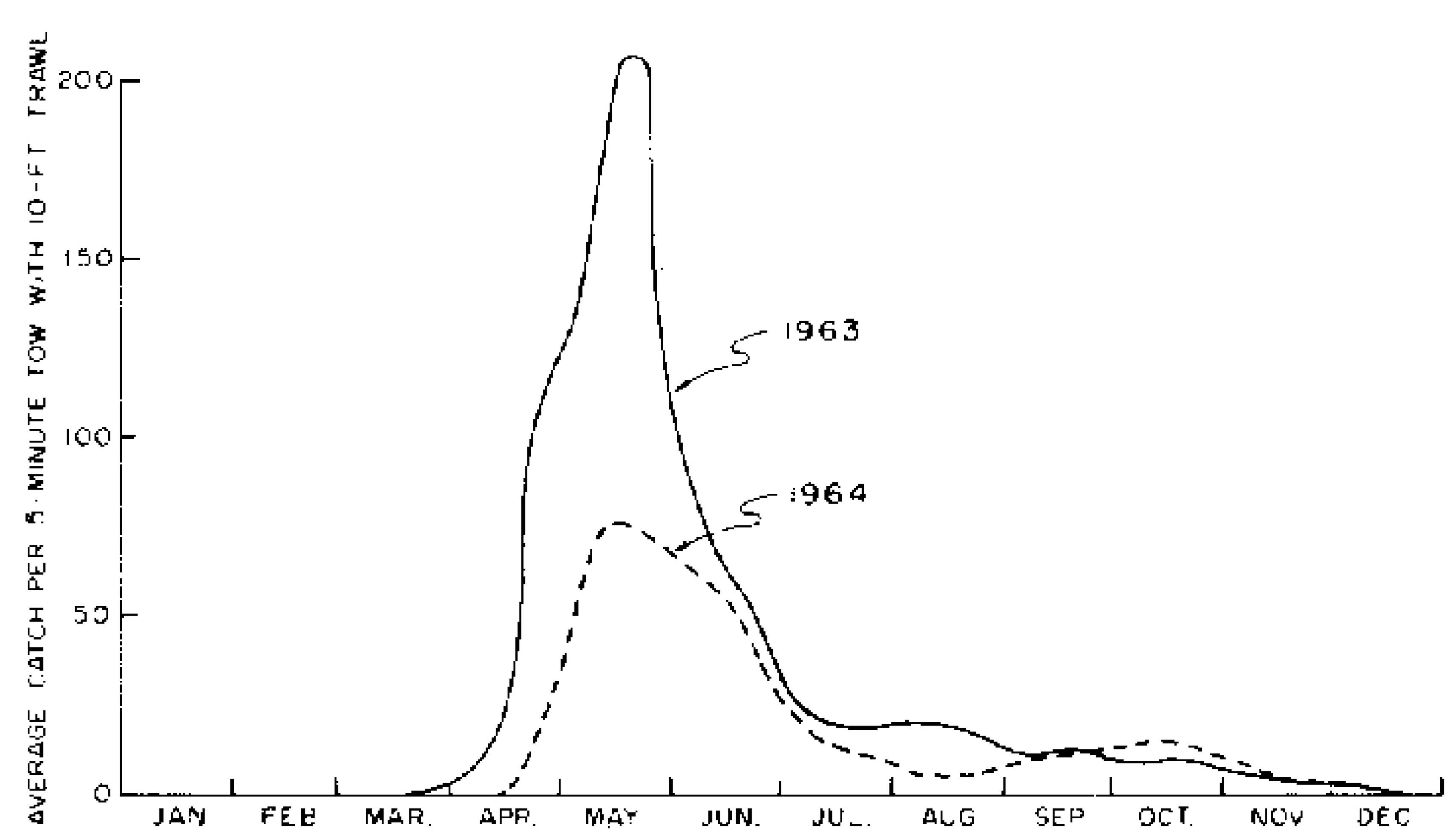


Figure 30.--Relative abundance of juvenile brown shrimp in the Galveston Estuary, Tex., during 1963 and 1964 as indicated from trawl sampling.

shrimp were concentrated in the areas of lower salinity of the estuary and, as they grew, migrated into the higher salinity environment. More specifically, juveniles of 41-100 mm. (1.61-3.94 in.) collected in 1963 were concentrated in salinities of less than 10.0 p.p.t., whereas juveniles 101 to 130 mm. (3.95-5.12 in.) were dispersed uniformly throughout the salinity gradient. Shrimp larger than 130 mm. (5.12 in.) were concentrated in salinities between 20 p.p.t. and 30 p.p.t. and were not collected in salinities below 10 p.p.t. In 1964, juveniles from 41 to 70 mm. long (1.61-2.76 in.) were concentrated in salinities below 10 p.p.t., and those from 71 to 115 mm. (2.77-4.53 in.) were concentrated in salinities between 10 and 20 p.p.t. Juveniles between 116 (4.57 in.) and 130 mm. were rather evenly distributed throughout the salinity gradient. Those larger than 130 mm. (5.12 in.) were caught mostly in salinities between 10 and 20 p.p.t. As in 1963, these larger shrimp were not caught in salinities below 10 p.p.t. During 1964, however, salinities in the estuary seldom exceeded 30 p.p.t.

It is not known to what extent salinity itself affects or controls the distribution of brown shrimp within the Galveston estuary. The immigration of postlarvae into the peripheral marshes, bayous, and smaller bays and subsequent movement of juveniles to the estuary's shore zones and open waters and thence to the lower bays and tidal pass can explain the apparent salinity-size relation. This pattern of movement involves the concentration of small shrimp in the estuary's peripheral areas that are generally less saline than the adjacent bays and the subsequent passage of the larger juveniles toward the Gulf through waters of ever-increasing salinity.

Bottom Fauna Study--Distribution and Relative Abundance of Rangia Cuneata

The first phase of an ecological study of the Galveston estuary was to describe the distribution and relative abundance of mollusks within the estuary. Ninety-three species of mollusks were collected and identified. A dredge was towed at each of 65 locations once during winter, spring, summer, and fall in 1964. Sampling locations were dispersed throughout the estuary (see U.S. Fish and Wildlife Service Circular 183, p. 51) to include each of the major types of environment. The composition of bottom sediments and many of the estuary's hydrological characteristics were also determined. Detailed evaluation of these data will require considerable time, although a preliminary appraisal has yielded meaningful results.

A portion of the data relating to the clam, Rangia cuneata, and the conclusion derived therefrom are presented here as an example of the information we have obtained for each of the 93 species of mollusks in the Galveston estuary. Rangia cuneata Gray is one of the more important components of the estuarine fauna. It inhabits many of the Gulf estuaries where it is an important food for fish, crabs, and shrimp. During 1964, the distribution and relative abundance of this animal in Galveston estuary varied considerably. In the winter it was caught in less than 5.0 percent of the estuary. This figure probably is biased because when water temperatures are depressed, the clam evidently buries deep into the bottom sediment and out of reach of our collecting gear. During spring and summer, however, numbers of this clam increased and by late summer it was found in about one-third of the entire estuary (fig. 31).

Significantly, this animal was generally restricted to those areas of the estuary that received large volumes of river water or marsh drainage--the areas of low and intermediate salinity. The clam was abundant only in the lowest salinity portions of the estuary. It was not collected where the average annual salinity exceeded 18.0 p.p.t. (fig. 32).

Rangia was found in every major sediment type in the estuary and thus occupied sediments

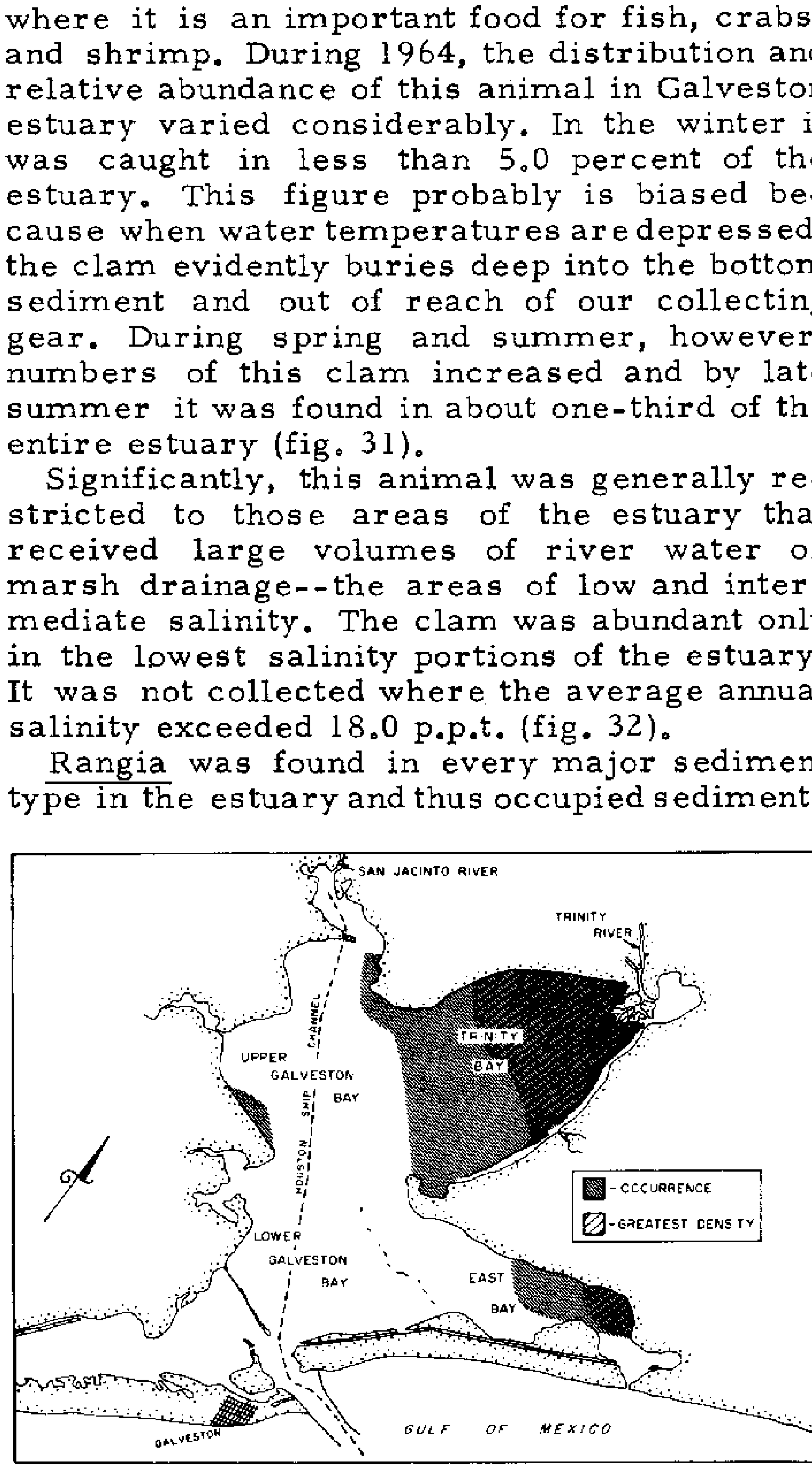


Figure 31.--Distribution and relative abundance of Rangia cuneata in Galveston estuary during late summer 1964.

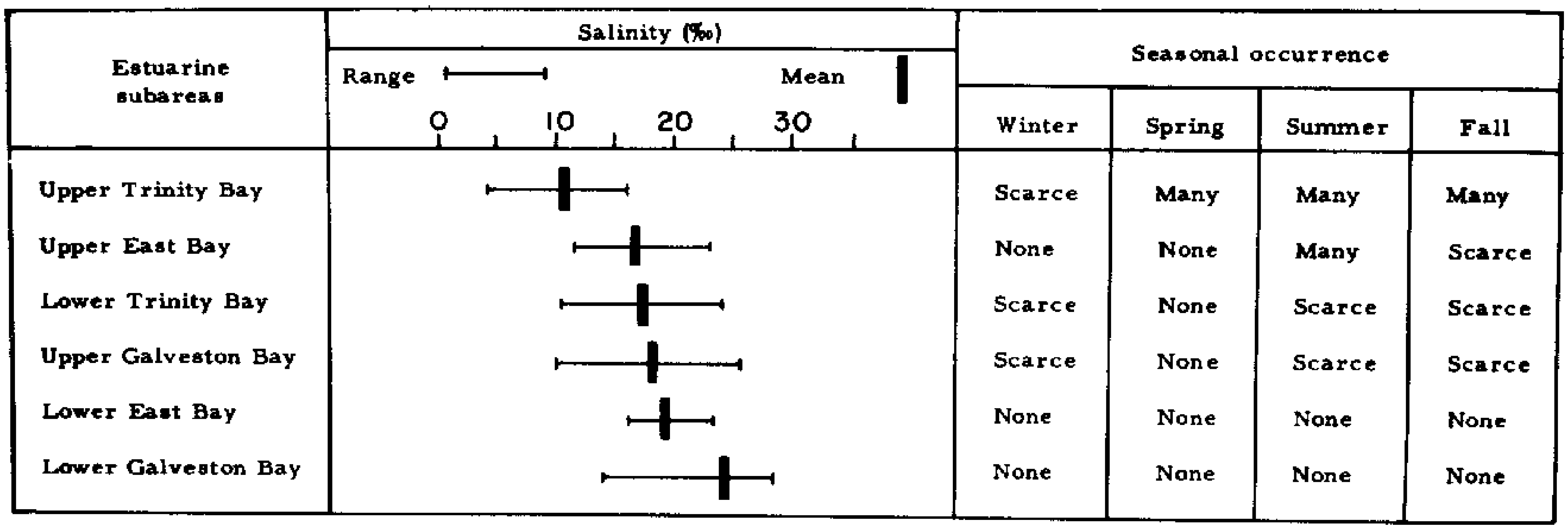


Figure 32.--Occurrence of Rangia cuneata in the Galveston estuary in relation to salinity, 1964.

having considerable variation in percentage composition of the sand, silt, and clay. Rangia was not abundant, however, if the sand, silt, and clay constituents exceeded 80, 30, and 65 percent, respectively, or if sand and clay comprised less than 12 and 14 percent, respectively, of the bottom sediment (fig. 33).

Reliable quantitative data are difficult to obtain with the dredge we used; a much improved collecting device is needed if we are to describe accurately the population density of the many species of bottom dwelling organisms. One such device (fig. 34), an underwater "vacuum cleaner" that removes intact all of the animals and sediments from a known area or volume of bottom, is being tested.

Jack C. Parker, Acting Project Leader

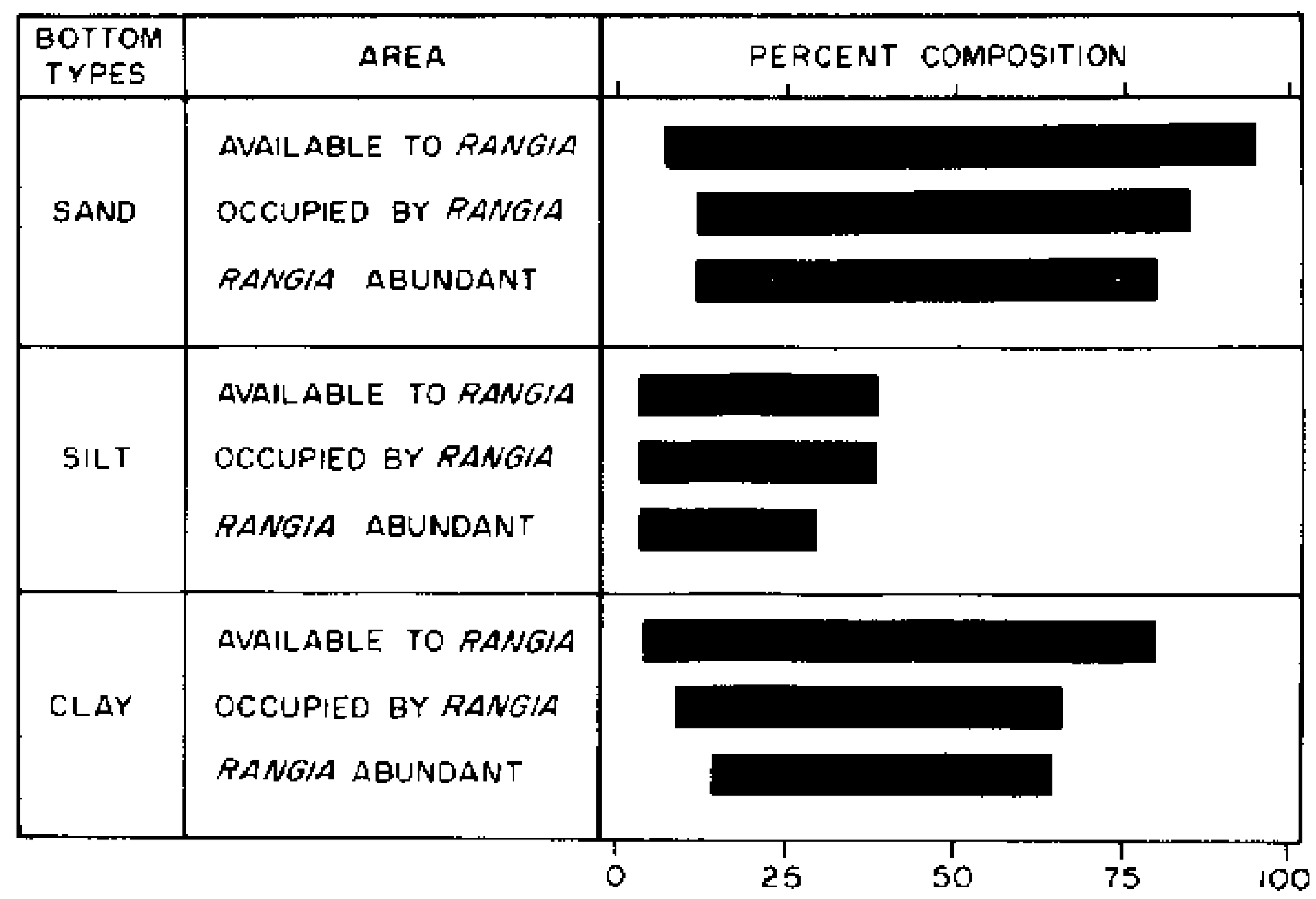


Figure 33.--Distribution of Rangia cuneata in Galveston estuary during 1964 in relation to bottom types.

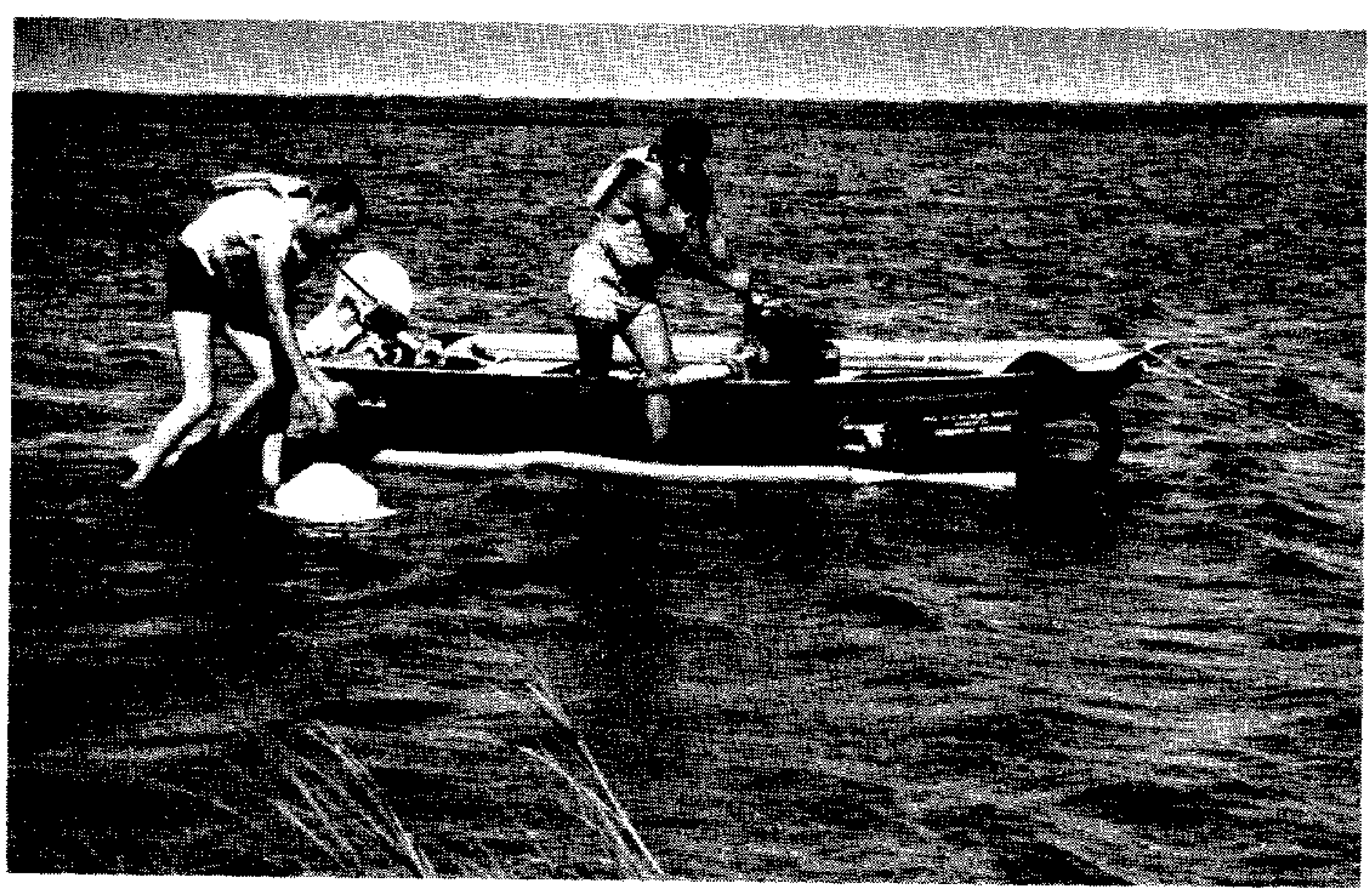


Figure 34.--New "vacuum cleaner" bottom sampler being tested. This device provides a quantitative sample by removing all sediments and animals from 1/10 m.^{2} (1.08 ft.^{2}) of the bottom to a depth of 5 in.

EFFECTS OF ENGINEERING PROJECTS

The importance of estuaries as breeding, feeding, and nursery grounds for many commercially important species of fishes, crustaceans, and mollusks is well known to the fisherman and to the professional biologist. About 98 percent of Texas commercial landings are of species in some way dependent on estuaries.

The estuary represents a habitat type known as an ecotone--a "buffer zone" or zone of transition--between the fresh water of the river system and the salt water of the sea. The characteristics of such a habitat are readily susceptible to change through natural or artificial alteration. Among the latter are many and varied forms of water development projects, such as impoundments on rivers and streams, dredging and channel construction, and real estate land fills in the estuaries. The cumulative effects of these projects upon the estuaries and associated fish production are likely to be extensive.

Though our present knowledge about the effects of such projects upon fishery resources is somewhat meager, it is important that we review project plans and advise the appropriate agencies what they might expect. In Texas, our personnel are working directly with representatives of the Bureau of Sport Fisheries and Wildlife, the Texas Parks and Wildlife Department, and other Federal and state agencies. Under this system of coordination, during fiscal year 1965 we reviewed plans and proposals for 326 construction projects in estuarine waters, 40 of which were adjudged to have potentially serious detrimental effects upon estuarine fishery resources. Drafts of 40 Bureau of Sport Fisheries and Wildlife reports evaluating the effects of construction projects on fish and wildlife resources also were reviewed.

Most engineering projects that we reviewed for their possible effect upon fishery resources in Texas are located near large population centers. About one-third of the projects are planned for construction either in the Galveston estuary (fig. 35) or on rivers and streams that supply fresh water and nutrients to the estuaries. After discounting those involving mineral development, almost half of all bulkheading-fill and dredging-channelization projects were slated for this estuary. As the human population of the Gulf coast increases, more engineering projects can be expected in other areas as well. More than 90 percent of all projects reviewed were privately sponsored.

Project personnel spent considerable time during the year on major projects in Texas (table 9) as well as other areas along the Gulf coast that required special study. We helped the Louisiana Wild Life and Fisheries Commission and the Division of River Basin Studies, U.S. Bureau of Sport Fisheries and Wildlife, review the results of the Mississippi River-Gulf Outlet Project so that the size of project-caused changes on adjacent estuaries and marshlands could be determined. Much effort also was spent revising and completing the estuarine fisheries section of the Fish and Wildlife report on the Bureau of Reclamation's Texas Basins Project.

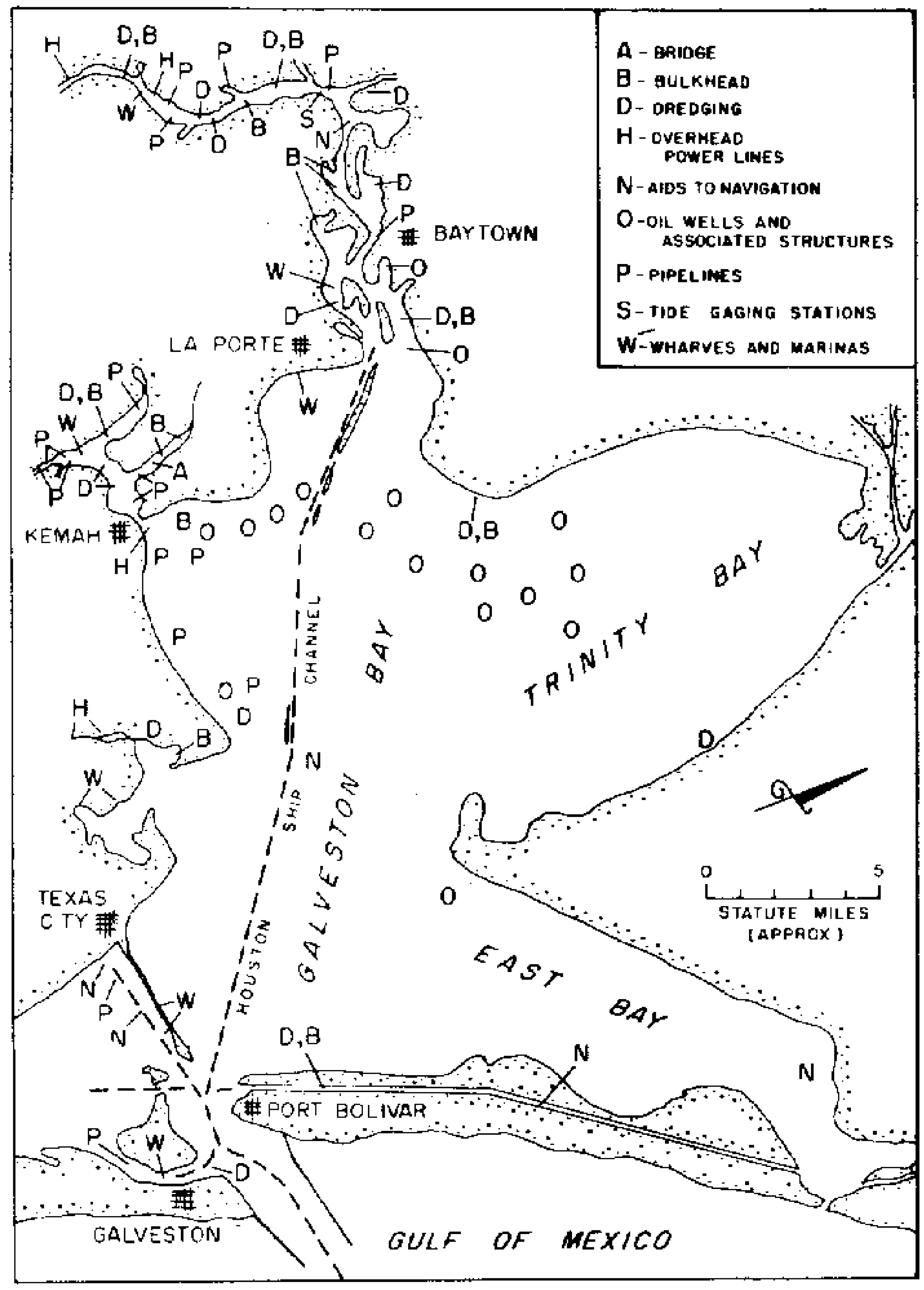


Figure 35.--Location in the Galveston estuary of privately sponsored projects reviewed during fiscal year 1965. Does not include locations of seismographic operations.

Many projects that involve diversion of fresh waters of rivers for municipal, industrial, and agricultural purposes are detrimental to the estuaries. The Corps of Engineers Lower Colorado River Project, however, may divert surplus fresh water from the Colorado River into eastern Matagorda Bay. This body of water used to receive the discharge of the Colorado River, but the river delta has formed across the estuary so water is now discharged directly into the Gulf of Mexico. The major supply of fresh water is now received by Lavaca Bay, a part of the Matagorda estuary.

Table 9.--Number, type, and location of engineering projects reviewed in fiscal year 1965, exclusive of seismographic and Gulf of Mexico operations

Texas estuaries	Projects			Type of project			
	Private	Federal	Total	Mineral development	Dredging and channelization	Bulkheading and fill	Other
Sabine Lake...........	6	1	7	1	3	1	2
Galveston.............	75	4	79	26	24	2	27
Matagorda.............	28	1	29	17	4	4	4
San Antonio...........	16	0	16	11	2	0	3
Aransas-Copano........	42	0	42	22	7	2	11
Corpus Christi........	32	0	32	15	3	2	12
Laguna Madre..........	28	0	28	20	7	1	0
Rivers and streams....	77	16	93	2	16	6	69
Total.............	304	22	326	114	66	18	128

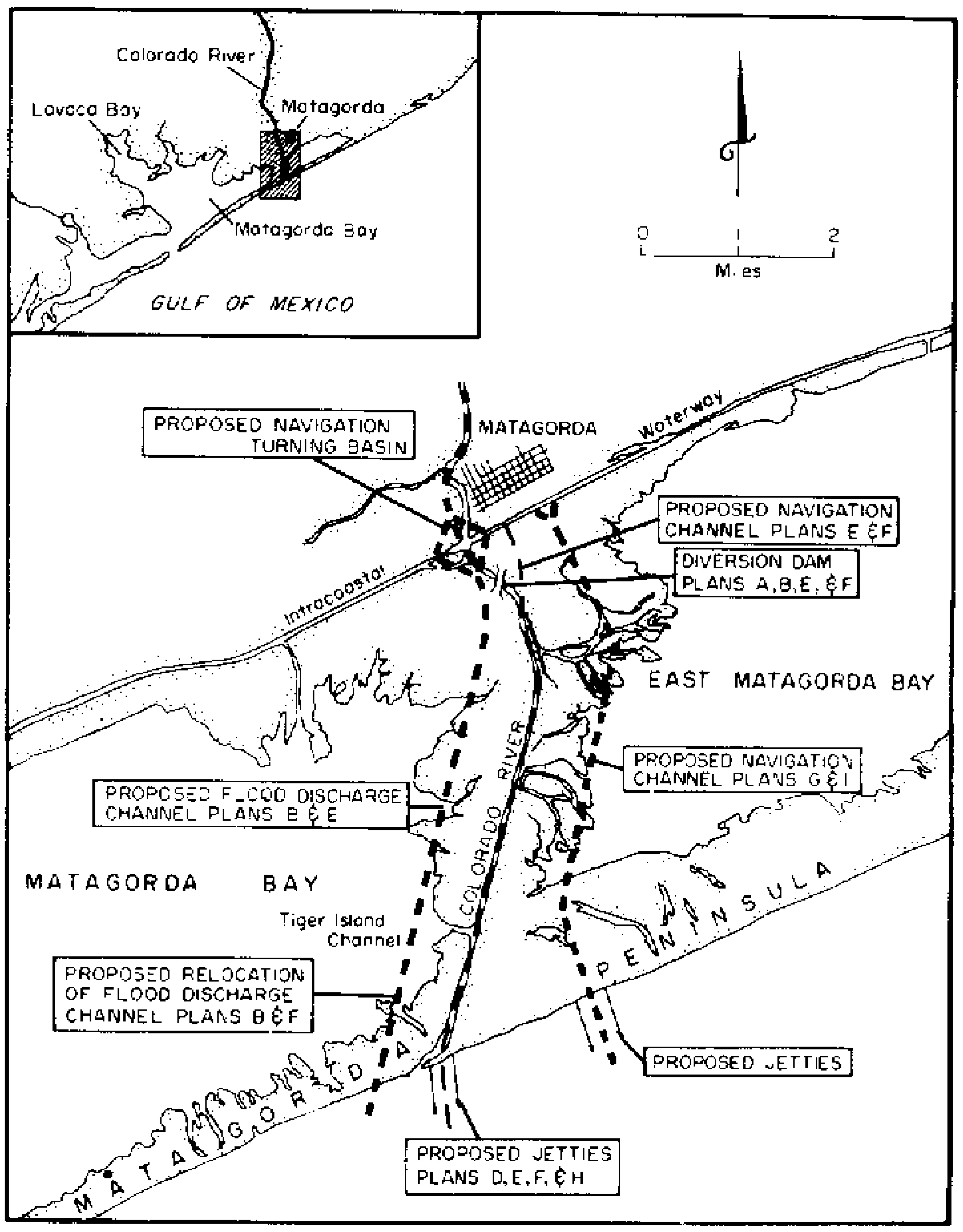


Figure 36.--Map showing various proposed plans of improvement on the lower Colorado River, Tex.

Nine plans under consideration to develop the lower Colorado River area provide for various combinations of separate and combined flood release and navigation channels (fig. 36).

Plan "A" consists of a new flood discharge channel emptying into eastern Matagorda Bay about 10,000 ft. downstream from the Gulf Intracoastal Waterway and a diversion dam across the present flood discharge channel (Colorado River Channel). Navigation improvement is not included.

Plan "B" consists of a new flood discharge channel to the west paralleling the present flood discharge channel and includes continuous spoil embankments on both sides. Navigation improvements are not included.

Plan "C" would improve the present flood discharge channel by raising the west and east banks of the Colorado River through spoil deposition.

Plan "D" consists of all features of Plan "C" plus a jettied entrance channel in the Gulf of Mexico.

Plan "E" consists of the flood control improvements of Plan "A" plus the improvement of the present Colorado River Channel for navigation. A jettied entrance as in Plan "D" and a slight realignment of the channel for navigation from about 5,000 ft. below the Gulf Intracoastal Waterway to the Waterway is also included.

Plan "F" consists of the combination of the flood control features of Plan "B" and navigation improvements of Plan "E".

Plan "G" consists of existing channel improvements as in Plan "C" for flood control with a new navigation channel east and parallel to the present channel. Continuous spoil banks on both sides of the new channel would separate it from east Matagorda Bay on the east and from the Colorado River on the west.

Plan "H" consists of improving the existing flood discharge channel for navigation along its present alignment and includes the jettied entrance channel and plugging openings into eastern Matagorda Bay.

Plan "I" consists of the new navigation channel of Plan "G" with no improvements for flood control.

Plans "B," "F," "G," and "I" would isolate vast expanses of the estuary so that they could no longer be used as nursery areas by estuary-dependent species. The proposed shunting of fresh water into eastern Matagorda Bay through adoption of Plans "A" and "E" would simulate the desirable conditions that previously existed and now occur in Lavaca Bay. The discharge from the Colorado River will become extremely important for maintaining high-quality estuarine habitat because of plans to divert fresh water from Lavaca Bay.

Richard A. Diener, Project Leader

EXPERIMENTAL BIOLOGY PROGRAM

This program continues the investigation of environmental influences on shrimp. Factors being studied include temperature, light, salinity, parasites, and food.

Continued research on shrimp parasites revealed that tapeworms common in shrimp of the Galveston estuary (1) are probably not significant sources of shrimp mortality, (2) will live at least 5 wk. in shrimp, and (3) seem to be much more common in shrimp from some bays than from others. These findings favor the possible use of parasites as biological shrimp "tags," which may permit the tracing of shrimp stocks from specific bays to offshore fishing areas and spawning grounds. Such a tool would be of considerable value in determining the contribution of specific bays to the offshore fishery.

Studies of shrimp behavior provided new insight into the swimming-speed capabilities of postlarvae of brown shrimp and the responses of white shrimp to low temperature. The results will be useful in interpreting the movements of these animals in nature.

Experiments on laboratory growth and survival were of several types. The influence of light on growth of postlarval brown shrimp was found to be negligible. This conclusion strengthens confidence in our previous shrimp growth data obtained from experiments requiring the use of light. Another study dealt with possible effects of laboratory handling on growth and survival of shrimp. Results indicated no effect, again confirming the reliability of the methods we use in survival and growth studies.

Measurements of the efficiency with which individual brown shrimp convert food into growth suggest variation between animals of the same size. This type of variation may cause significant differences between individual growth rates of shrimp.

Our research into effects of environmental factors on shrimp growth has thus far been restricted to postlarval and early juvenile stages (up to about 2 in. long). Under laboratory conditions, growth of shrimp above this size has generally been negligible. Recent studies have been directed toward improving this later growth so that it may be used to measure the suitability of controlled environmental conditions for larger shrimp.

This year saw the successful conclusion of growth and long-term survival studies on young white and brown shrimp. Results of these studies have indicated that there are relatively broad zones of temperature and salinity tolerance (in terms of survival) for young brown and white shrimp. Growth data demonstrate that temperature has a far more important effect than salinity on the growth of either species during their postlarval and early juvenile stages.

Experimental comparisons of white shrimp with brown shrimp taken in spring and summer have provided strong evidence for differences between species in temperature tolerance. This additional knowledge of the environmental requirements of both shrimp species will permit a better understanding of seasonal distribution of shrimp in estuaries.

The field use of automated temperature-recording equipment has permitted the most complete temperature characterization to date of two types of estuarine situations available to postlarval and juvenile shrimp.

David V. Aldrich, Program Leader

BEHAVIOR AND ECOLOGICAL PARASITOLOGY

Previous field phases of this project indicated that tapeworms are frequent parasites of brown and white shrimp in the Galveston area, and that the infection is acquired during the estuarine portion of the shrimp's life cycle. Continued research has provided information necessary for the evaluation of tapeworms as potential biological "tags" for shrimp. A 5-wk. study of a captive brown shrimp population showed no significant difference between the population's initial incidence of tapeworm infection and that of either short- or long-term survivors. The initial incidence of parasites was 83 percent; that of shrimp dying within the first day of captivity was 78 percent. Seventy-five percent of the 5-wk. survivors were infected. There were no statistically significant differences between any two of these values. The results suggest that the worms do not contribute either to very short-term or 5-wk. mortality and that the life expectancy of the tapeworm in shrimp exceeds 5 wk. These findings tend to favor the possible use of a parasite as a biological shrimp "tag."

It remained, however, to determine whether significant differences existed between infection rates of shrimp from different bays. As a result we have made a few comparisons of rates of worm incidence in shrimp collected from various bays. We have sampled shrimp from four Texas bays--Sabine Lake (estuary of the Sabine River), the Galveston Bay system, the Matagorda Bay system, and Corpus Christi Bay. Groups of shrimp compared in this study were collected on the same day and were of the same species and size. The May and June samples probably represent the bulk of the brown shrimp populations of these bays for this year. Sabine Lake shrimp were less frequently infected with tapeworms than shrimp from the three bay systems to the southwest (fig. 37).

The movement of postlarval shrimp into bays from offshore spawning areas is an accepted feature of the Penaeus life cycle. The relatively large distances involved and the relatively small size of the postlarvae have caused speculation as to whether these animals move actively or passively. Interest in this problem has led to laboratory measurements of postlarval swimming speed. The time required for individual postlarvae of brown shrimp to swim a known distance was used to estimate speed. The mean value of 40 determinations (made at 23° C. (73° F.) and 24 p.p.t. salinity) was 4.7 cm./sec. (about 1-7/8 in./sec.). Assuming uninterrupted movement at this rate and ignoring effects of water movement, we can extrapolate this value to 2.6 miles per day. Further study will be required to determine whether or not postlarvae can sustain these rates and to test for the possible influence of environmental factors on postlarval movements. From field observations of R. D. Ringo (Estuarine Program), we do know, however, that brown shrimp postlarvae move through Galveston Bay at an average speed of 2 miles per day.

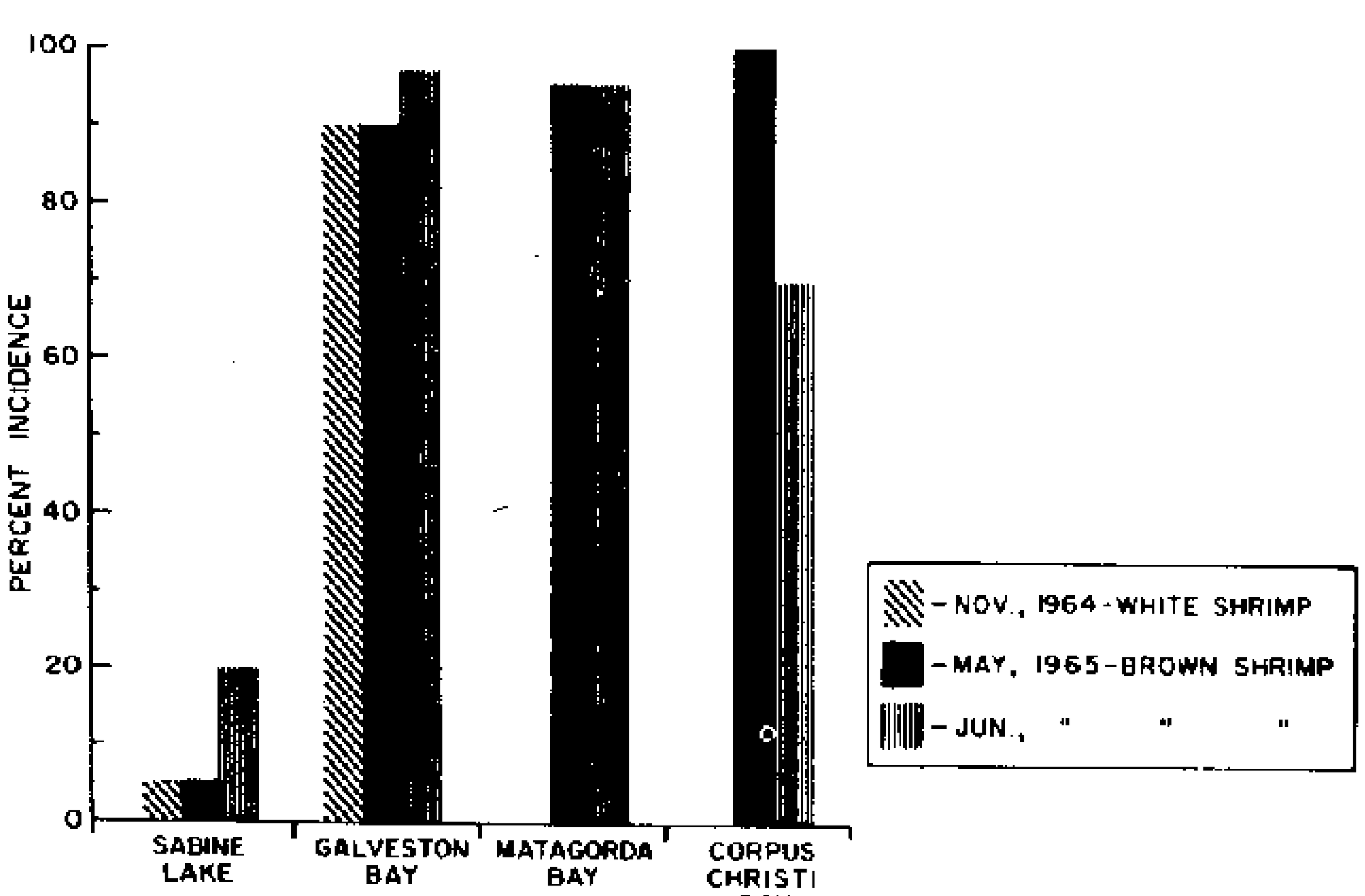


Figure 37.--Incidence of tapeworms in shrimp from Texas estuaries--Sabine Lake, Galveston Bay, Matagorda Bay, and Corpus Christi Bay, 1964-65.

On the basis of field observations, earlier workers have suggested a relation between winter water temperature and the size distribution of white shrimp; the larger shrimp are believed generally to occur in the highest temperatures. No direct observations have been made, however, of the effect of low temperature on shrimp of various sizes under laboratory conditions where other environmental factors could be controlled. Four experiments were conducted to supply such information. In each test, 10 white shrimp from 60 mm. (2-3/8 in.) to over 100 mm. (about 4 in.) total length were simultaneously exposed to decreasing temperatures. Loss of equilibrium was selected as a rapid and sensitive behavioral "end-point." As the experimental temperatures fell to 14°-12° C. (57.2°-53.6° F.), the larger (100-130 mm. = about 4 to 5-1/8 in.) animals in each group became unable to maintain equilibrium but lay on their sides or backs. Greater temperature decreases of about 1° C. (1.8° F.) were necessary to produce similar symptoms in the smaller shrimp. Low-temperature susceptibility in white shrimp is, then, related to animal size; suggesting that there is a physiological mechanism through which temperature governs the winter distribution of white shrimp.

The growing body of evidence indicating important effects of temperature on growth and survival of shrimp has intensified our need for more complete temperature data from the field. The fact that shrimp can burrow into substrates beneath the water compounds the problem of measuring features of the different environments inhabited by these animals. At present we are approaching this problem through the use of automatic, continuously recording temperature equipment at our East Lagoon laboratory. The temperatures recorded include those of the air, surface water, bottom water, and substrate, all under the laboratory, where water depth is about 6 ft. The recording speed and flexibility of the equipment have allowed us to attain a level of sampling intensity that would not be feasible with manual methods. As a result, the data are giving us a previously unobtainable insight into the magnitude and rate of estuarine temperature fluctuations. Already they have shown that rate of temperature change in the bottom water differs from that in the substrate. Temperatures of the substrate vary less rapidly than those near the bottom of the overlying water column. For example, during this winter's coldest period, bottom water temperature fell 3° C. (5.4° F.) in 12 hr., while substrate temperature was reduced only 1.5° C. (2.7° F.). Thus, it is possible that the burrowing habit of shrimp may at times provide a means of avoiding temporarily unfavorable temperature conditions.

These measurements are providing field information for the design of laboratory experiments to determine whether temperature differentials between water and substrate induce burrowing in shrimp.

In February, two additional thermistors were installed to compare the temperature regime of a very shallow peripheral inlet with that of the lagoon proper. As anticipated, the temperature fluctuations were considerably wider in the peripheral water and substrate than in the 6-ft.-deep water and its substrate (fig. 38). Furthermore, temperature differences between the shallow water and its substrate were much greater than those in the deeper location.

These temperature data have also indicated that the peripheral marsh during early spring is consistently warmer than the 6-ft-deep environment. Analysis of results for March and the first half of April indicates that 91 percent of the observed temperatures (bottom water and substrate) in the lagoon proper were lower than or equal to those at the shallow inlet. Weekly means for the two locations differed by 2° to 5° C. (3.6° to 9.0° F.). Differences were frequently marked, reaching 14° C. (13° vs. 27° C.) on one occasion. (These temperatures correspond to 25.2°, 55.4°, and 80.6° F., respectively.)

These temperature characteristics further support our consideration of the shallow peripheral area as a discrete ecological zone to be distinguished from the main body of the estuary. In view of the marked influence of temperature on the growth of young shrimp (as well as other organisms), it is possible that the temperature characteristics of the bay's very shallow peripheral zone, which the young shrimp first inhabit, may have an important bearing on estuarine productivity in the spring. The major annual influx of brown shrimp postlarvae reached Galveston Bay during this early spring period, according to the records of K. N. Baxter (Shrimp Dynamics Program).

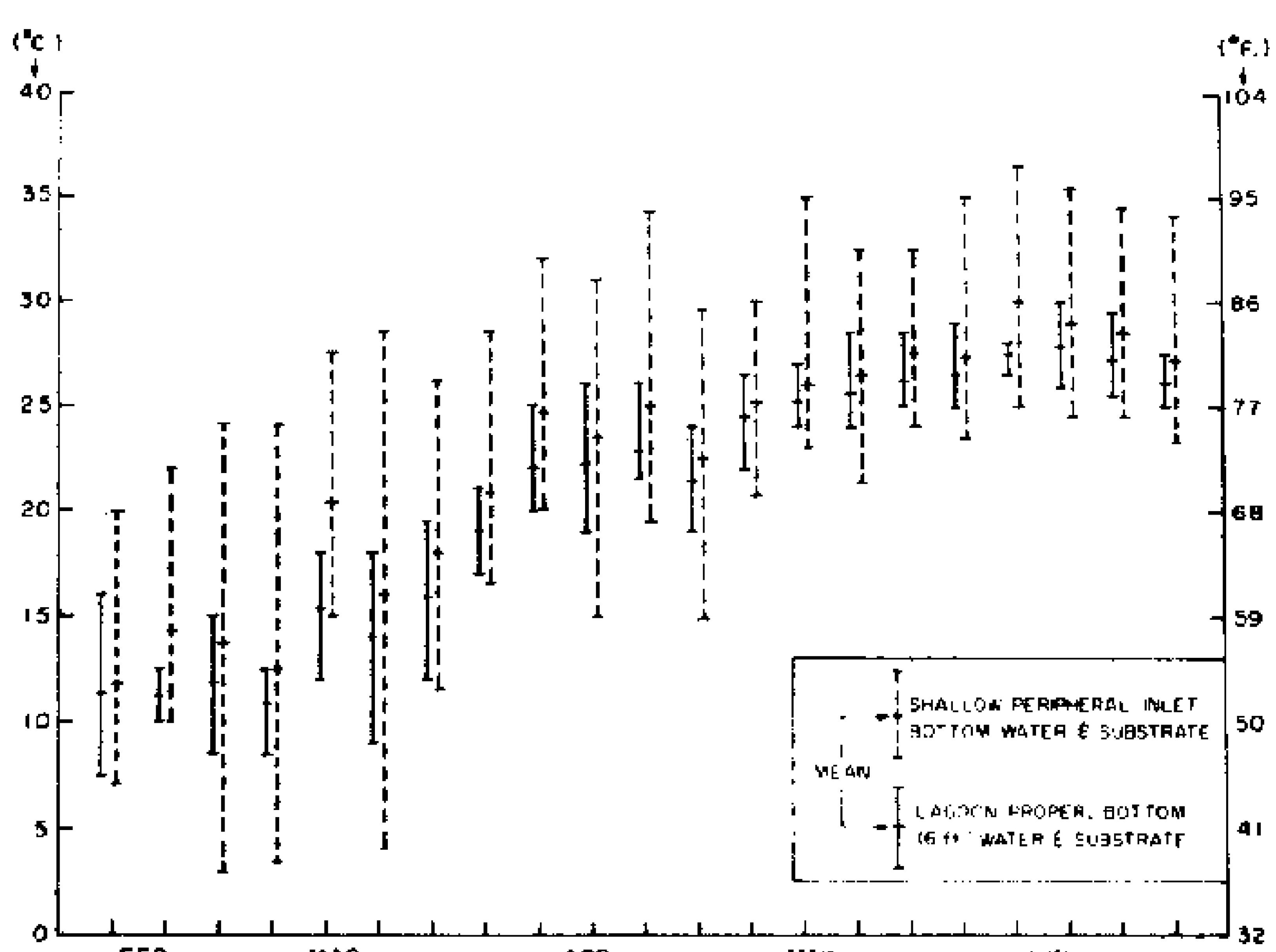


Figure 38.--Weekly temperature ranges and means in two estuarine situations--shallow peripheral inlet and lagoon proper--of East Lagoon, 1965.

From late April through June, there were less striking differences between weekly mean temperatures of the two situations and smaller ranges overall. Continued observations will provide data on summer temperature extremes and rates of change. We need this information as background for the design and evaluation of laboratory studies of how and why shrimp respond to temperature.

David V. Aldrich, Project Leader

SHRIMP METABOLISM

The metabolism project is concerned with differences in physiology between the commercially important brown and white shrimp. Although several of the studies discussed here concern growth, they began before the growth and metabolism projects were subdivided and as a result were conducted jointly by the two projects.

Postlarvae of both species enter the bays where salinities and temperatures may fluctuate widely. In the northwestern Gulf, most postlarvae of brown shrimp enter the bays in the spring; smaller numbers arrive throughout the summer. White shrimp postlarvae, however, reach the bays during late spring and summer. Thus, the postlarvae of the two species are exposed to somewhat different conditions during the period of active growth.

A previous study compared the effects of salinity and temperature upon the growth of spring brown and summer white shrimp postlarvae. The postlarvae of brown shrimp apparently withstood low temperatures (52° F.) far better than did the white postlarvae, whereas at 90° F. the white shrimp survived and grew slightly better than the brown shrimp. The spring population of brown shrimp postlarvae, however, had been accustomed to cooler temperatures than the late-summer white shrimp. To determine whether this difference in temperature tolerance was related to species rather than to temperature history alone, we studied postlarval brown and white shrimp collected at the same time (June) and, therefore, with the same temperature experience. Postlarvae of brown shrimp again survived better than white shrimp at the lowest test temperature (59° F.), and the white shrimp survived somewhat better at the highest test temperature (92.5° F.) (table 10). There was a greater effect of warm temperature upon growth rate of postlarval white shrimp than upon growth rate of brown shrimp (fig. 39). Postlarvae of white shrimp held 30 days at 92.5° F. were 8 mm. (0.31 in.) longer and twice the weight of those held at 77°, but at the end of the experiment brown postlarvae

Table 10.--Percentage survival of summer postlarvae of brown and white shrimp exposed to various combinations of salinity and temperature

Salinity	Temperature (°F.)							
	59		64.5		77		92.5	
	Brown	White	Brown	White	Brown	White	Brown	White
P.p.t.	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
2...............	(1)	--	49	79	--	--	--	--
5...............	32	20	--	--	--	--	52	96
25...............	100	80	--	--	100	82	100	90
40...............	100	88	98	90	--	--	86	98

[1] No tests made at combinations indicated by dashes.

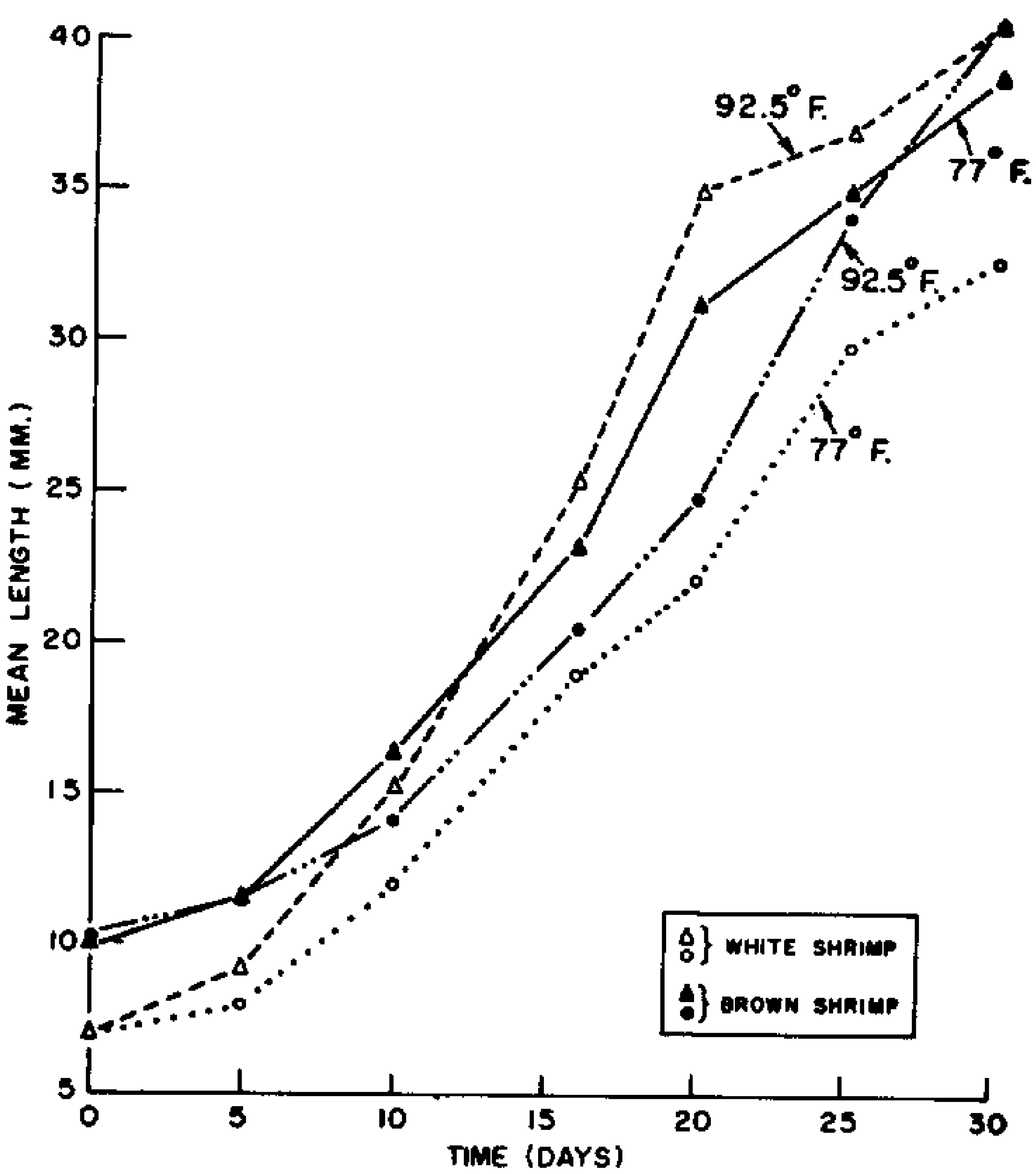


Figure 39.--Growth of brown and white shrimp postlarvae at 77° and 92.5° F.

at these two temperatures were almost identical both in length and weight.

At a single temperature, however, salinity did not seem to affect growth in either species. Once again it seems that growth may be affected more by the temperature than by the salinity of the environment. Furthermore, the data cited above confirm our earlier work which indicated that combinations of low salinity and low temperature were detrimental to the growth and survival of postlarval brown shrimp.

Since the growth of postlarval brown shrimp seemed to be influenced far more by temperature than by salinity, we made a more exhaustive study of the effects of temperature upon growth in this species. The effects of early spring temperatures (59° to 77° F.) were reported last year. Animals held at 77° F. for 30 days were almost twice as heavy as those held at 72.5° F. and almost 10 times as heavy as those held at 63.5° F. Because postlarvae arriving in the bays in late spring spend most of their lives at temperatures considerably higher than 77° F., our second study during the summer of 1964 tested the effects of temperatures of 77° F. through 95° F. The study yielded two notable results: survival was markedly reduced at 95° F., and all experimental animals died within 15 days. In contrast to the early spring study, which indicated a continuous increase in growth as temperature increased up to 77° F., temperatures above 77° had much less effect in increasing growth of brown shrimp postlarvae. This effect of high temperatures on growth in brown shrimp is also suggested by the salinity and temperature study illustrated in figure 39.

Ecologically, the differences in temperature and salinity tolerance between postlarval brown and white shrimp fit well with the environmental conditions actually encountered by most members of each species. Postlarval brown shrimp entering the bays in early spring are subjected to far lower temperatures than those encountered later by the whites. Furthermore, the brown shrimp appear less well adapted to survive the high temperatures of midsummer in areas at the edges of the bays. The postlarval white shrimp, however, appear to do less well at low temperatures. White shrimp apparently grow better at temperatures above 77° F. At late spring and summer temperatures, both species tolerate a wide range of salinities--a factor which may fluctuate in the bays during all seasons.

Possible chemical differences between the two species are also being studied, for we

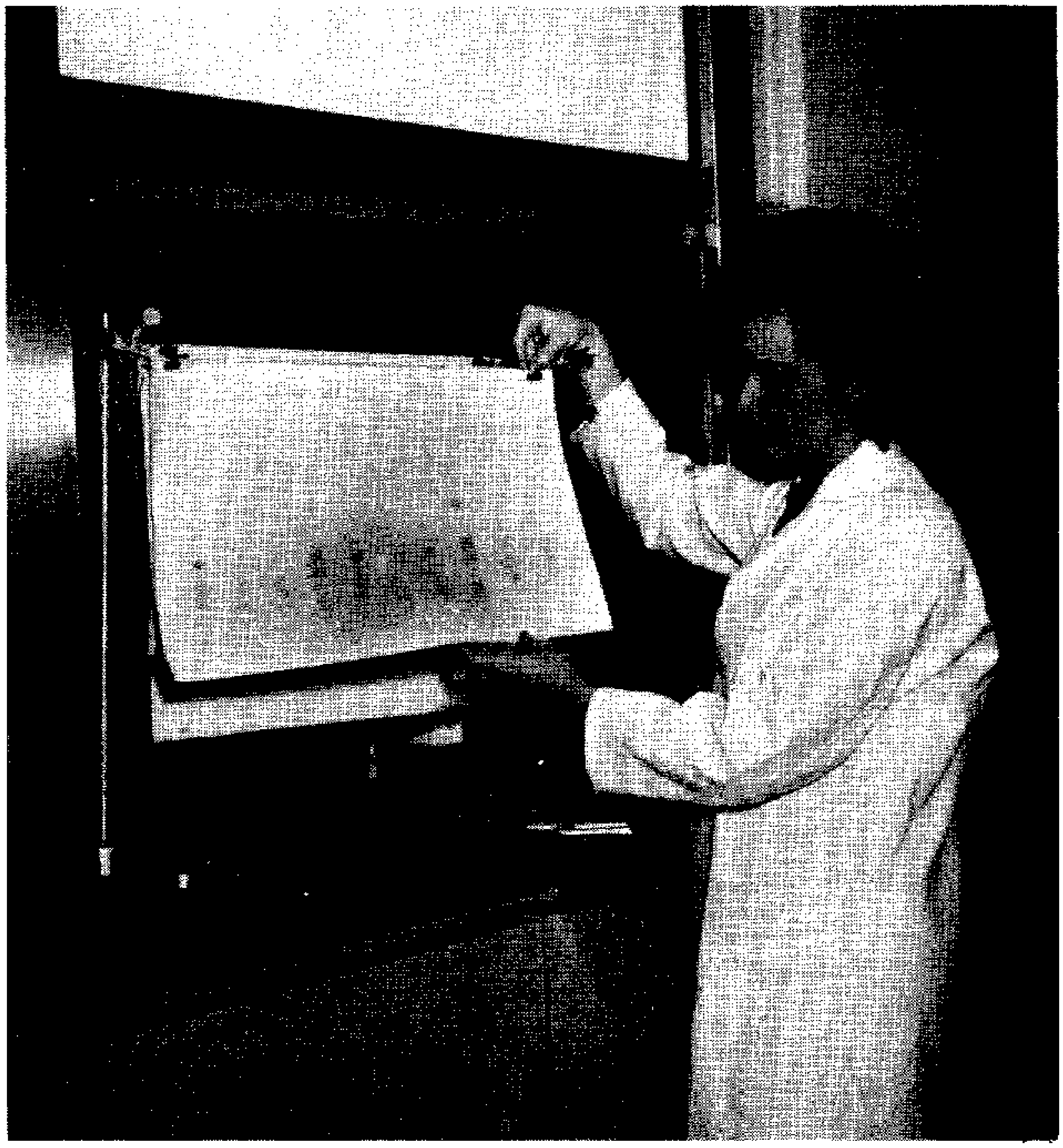


Figure 40.--Examining a chromatogram of extracts from the tail muscle of various shrimp species.

hope that a chemical method of identification may be developed. Such a method would be useful in identifying species of postlarvae during stages when there are few anatomical differences. The technique of paper chromatography (fig. 40) is being used now. Preliminary results suggest that only quantitative differences may exist between the amino-acid compositions of the two species.

Zoula P. Zein-Eldin, Project Leader

GROWTH AND SURVIVAL OF SHRIMP

Experiments during the past year were designed to determine the influence of various factors on growth of white and brown shrimp.

Since most of our previous laboratory-controlled growth experiments were illuminated, we thought it necessary to determine what effect, if any, various light regimes have on the growth of postlarval shrimp. We tested three conditions--constant illumination, constant darkness, and intermittent light and dark (12 hr. light and 12 hr. dark). Animals were kept at 25° C. (77° F.) and brine shrimp larvae supplied as food (fig. 41). Growth for both white and brown shrimp was good, about 0.7 mm. (.03 in.) per day for each species at the various conditions. No significant difference was seen between the three experimental groups. Thus light, as used in past experiments, has no effect on growth of postlarval brown and white shrimp.

Data from past experiments reveal that after a period of growth in the laboratory the range of sizes is frequently wide within a group of test animals. We do not know whether this difference in size is related to food consumption of the individual shrimp or to some other factor.

In an attempt to determine the cause of this disparity in growth, we made one experiment to confirm or eliminate food consumption as the controlling factor. In this experiment, four postlarval brown shrimp were isolated in 1-l. (0.9 qt.) containers, one per container. We kept individual records of daily growth and food consumption. Sampling just prior to and after feeding every 24 hr. gave an estimate of the number of brine shrimp consumed daily (fig. 42). During the time the

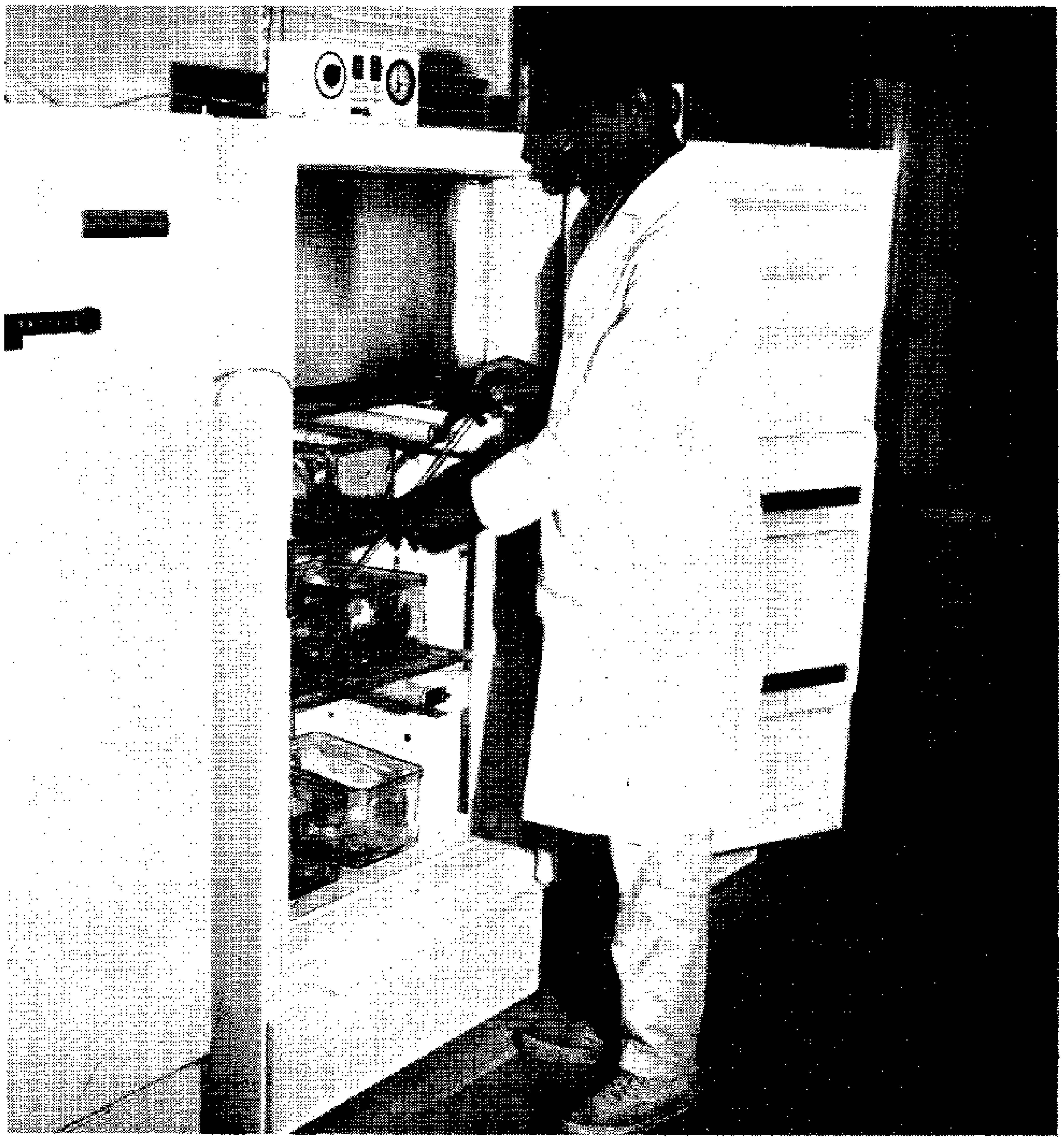


Figure 41.--Feeding brown shrimp during illumination experiment.

animals grew from 18 to 38 mm. (0.71-1.50 in.), food consumption of the four shrimp, A, B, C, and D, respectively, was 5,400, 5,700, 6,400, and 6,100 brine shrimp per day; rate of growth was .04, .04, .04, and .05 in. per day; and feeding efficiency was 43, 43, 34, and 45 percent. This variability in efficiency may contribute to the wide variation in growth of our experimental animals. More work of this type is in progress.

Attempts in the laboratory to induce growth in shrimp 2 in. or more in length have generally been unsuccessful. Brine shrimp larvae are excellent food for postlarval shrimp, but this diet is impractical for larger shrimp because of the extremely large number of larvae required to feed each animal. In view of this problem, a study was made to find a diet that would support growth in juvenile and subadult shrimp under laboratory conditions. In an experiment, individual subadult white shrimp were isolated in 1- and 15-gal. aquaria. Three diets were tested--canned liver (commercial cat food); canned, minced clams; and frozen, mature brine shrimp. Mortality in the small aquaria was high (77 percent) probably because of bacterial fouling which seemed less in the larger tanks. Growth in the group fed liver and the group fed clam was actually negative in some animals; weight decreased as much as 0.5 g. (.018 oz.) in 28 days. Very slight weight increases, averaging about 0.6 g. (.021 oz.) in 28 days, occurred in shrimp fed frozen brine shrimp. We are continuing this study and are evaluating other diets.

Several short-term experiments with juvenile and subadult white shrimp (62-132 mm. or 2.4-5.2 in.) were carried out to test survival under various combinations of temperature and salinity. Test animals were isolated in compartmented containers and held at test conditions for 24 hr. At the end of this period, we noted the survival. At the midrange of both temperature (25° C. or 77° F.) and salinity (25 p.p.t.) survival was good. Poor survival was evident below 12.5° C. (55° F.) and 13 p.p.t. and also above 32° C. (88° F.) and below 10 p.p.t. salinity. At high salinity (40 p.p.t.) survival was varied (0-100 percent) at both 25° C. (77° F.) and 35° C. (95° F.), indicating that these are marginal conditions (fig. 43). We plan further tests to obtain information at various levels of temperature and

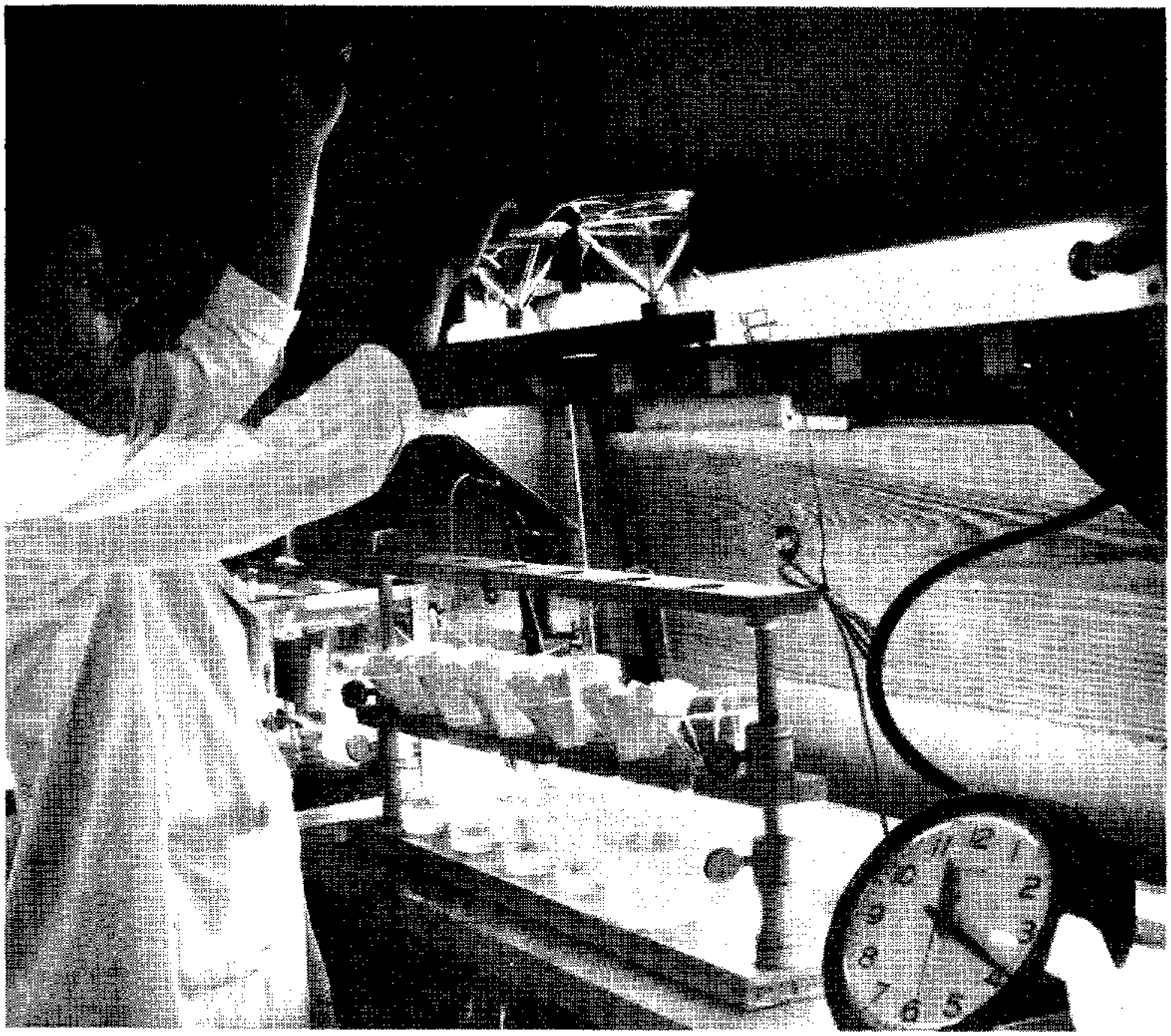


Figure 42.--Sampling from experimental shrimp containers for quantitative measurement of food consumption.

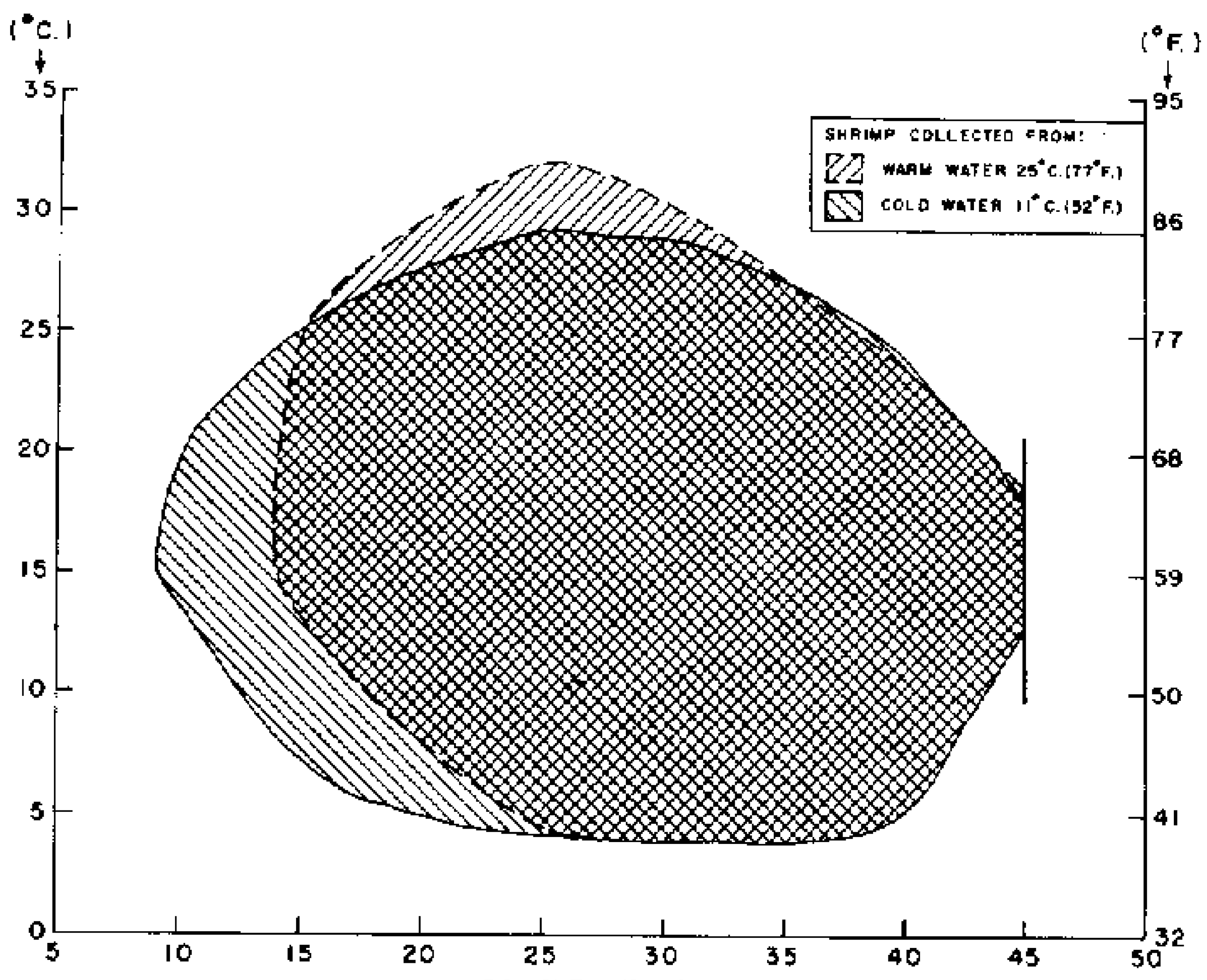


Figure 43.--Survival of juvenile and subadult white shrimp at various temperature and salinity levels.

salinity for white shrimp of all sizes. We will also make comparable tests with brown shrimp.

George W. Griffith, Project Leader

EFFECTS OF ELECTRICAL STIMULATION ON BOTTOM INVERTEBRATES OTHER THAN SHRIMP

In our research on the responses of marine annelid worms to electric shock, we have experimented with various species of polychaetes obtained from beach areas. In nine of these species, a pulse length in excess of 200 μsec. (microseconds) was necessary to produce a twitch or contraction. A field strength of from 0.3 to 2.0 v. (volts) was necessary for threshold response. The pulse rate used for determining threshold levels of field strength and pulse length was 3 pulses per second. Two other species are unresponsive to electrical stimulation of any type available to the experiment.

In a second phase of the project, polychaetes living in substrate were stimulated by varied field-strength voltages and rates for periods of time ranging from 5 sec. to 30 min. In no instance did a worm emerge from the substrate. When stimulated electrically, worms that were visible responded by contracting and sometimes moving deeper into the substrate. No worm moved toward one electrical pole or the other.

Experiments to determine mortality caused by stimulation were inconclusive because of difficulty in maintaining worms in the laboratory. The five species tested withstood up to 10 pulses per second of 250-μsec. length and 35-v. field strength for as long as 1 hr. with no mortality. The most sensitive species of polychaete studied here died within 2 to 4 min. at the above rate and pulse length with a field strength of 5 to 10 v.

We have found that continued test stimulation of annelids at 200-μsec., 3 pulses per second, 0.6 to 6.0 v. leads to lessened response and finally no response. Different species lost their response at different times, ranging from 30 sec. to 7 min. The stronger pulses, which produce stronger contractions, increase the rate of fatigue.

We are making similar studies on species taken from an inshore shrimp habitat. Presence or absence of response is being noted to permit comparisons between typical species from this area and those from the beach zone.

R. W. Menzel, Project Leader

Florida State University
(Contract No. 14-17-0002-111)

CHEMISTRY AND SEA-WATER LABORATORIES

ESTUARINE WATER ANALYSIS

The chemical analyses of estuarine water samples give evidence of irregularity that we think is caused by a lack of representative samples. This shortcoming could be caused by particulate matter, which makes these waters difficult to identify chemically. Data on total nitrogen and total phosphorus are particularly affected. We have begun an investigation of sampling and analytical procedures to determine whether we can do anything to increase the reliability of estuarine chemical data.

TOTAL NITROGEN ANALYSIS

The maximum number of total nitrogen analyses per day has been more than doubled by eliminating the need to digest the samples in a fume hood. We learned that by plugging the Kjeldahl digestion flasks with glass wool, sulfuric-acid fumes are effectively contained within the flask during digestion. Thus, the operation can be carried on in the laboratory proper without fear of contaminating the air with noxious fumes. The use of glass wool has increased our maximum daily production from about 20 to over 50 analyses.

SAMPLE FILTRATION

It is not always advisable to use a filtering medium to remove particulate matter from a water sample before chemical analysis. The filter material can alter the composition of a sample not only by removing particulate matter but also by adsorbing ions from solution. We learned, for example, that if 180 ml. of a particulate-free, fresh-water sample containing 4.5 μg.at./l (microgram atoms) of dissolved copper per liter is passed through a small plug of glass wool in a funnel, the copper content is reduced to 0.7 μg.at./l. or by a factor of about 6. The absorption effect of the wool seems to be inversely proportional to the salinity of the sample. Thus, salt water (S = 27 p.p.t.) with an initial copper content of 3.3 μg.at. of copper per liter when similarly filtered has a content of 2.7. Filter paper has a comparable effect.

We are now investigating the results of filtration on all of our analyses.

RED-TIDE TOXICANTS

We completed the experimental evaluation of six toxicants that have been shown in previous reports to be sufficiently promising under laboratory conditions to be considered for control. Final tests consisted of reestimating minimum toxic levels for each of the six materials in a culture of _Gymnodinium breve_ made from samples taken from a recent red-tide outbreak (spring of 1963). Previous work had been based on _G. breve_ that had been maintained in the laboratory since 1952. In artificial medium, the newer culture of _G. breve_ seems to be less vulnerable to the toxicants than the older one. In Florida-water medium, however, its reaction toward the toxicants is about the same.

SEA-WATER LABORATORIES

The facilities of the sea-water laboratories have been used not only by our personnel but also by other research organizations. University of Texas Medical School personnel continue to use the sea-water laboratories for work on the molecular basis of brain function in fish (described in our annual report for fiscal year 1964). University of Georgia personnel used our lagoon laboratory to study the effects of various wavelengths of light on the retinal pigment migrations in brown and white shrimp. A Texas A&M University researcher used the same facilities to study the effects of certain mollusk predators and salinity ranges on the brackish-water clam, Rangia cuneata.

About half of the recirculating laboratory facility has been taken over for research on shrimp spawning and larval culture. For these studies, we installed a 150,000-B.t.u. (British thermal unit), salt-water heater and various smaller temperature-regulating and nutrient-flow control devices.

Mechanically, we had a good year. One forced shutdown of the recirculating system was caused by city power failure, and two at the lagoon laboratory by extremely low tides. The intake end of one of the main pumps at the lagoon laboratory has been extended several feet to prevent future difficulty.

During the year, 338,000 gal. of salt water were added to the recirculating system. The monthly rate of these additions is shown in figure 44.

The chemistry of the recirculating water is more or less typical of that of waters of such an enclosed system. The decomposition products, ammonia and particularly phosphate and nitrate, are very high. From December 27 to March 15, only 4,000 gal. of water were added to the system. The decline of salinity during this period resulted from fresh-water contamination, which was finally traced to a leaking tapwater line. Beginning April 1, all water in the system was replaced with "new" water, and continued replacement has kept levels of nitrate and phosphate relatively low.

Kenneth T. Marvin, Supervisory Chemist

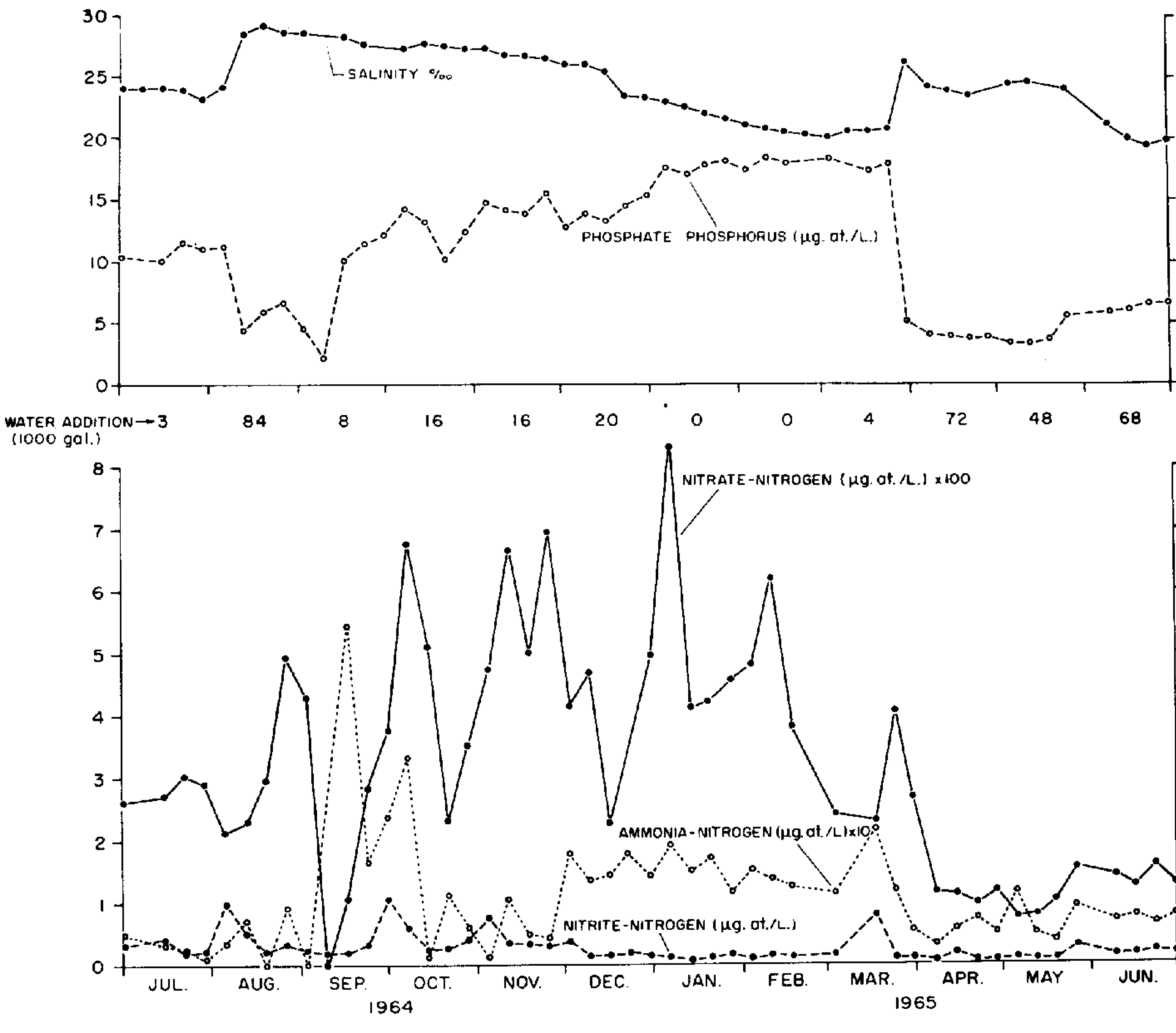


Figure 44.--Chemical composition (weekly averages) of water in the recirculating sea-water laboratory, 1964-65.

OYSTER GROWTH EXPERIMENT IN EAST LAGOON

An investigation was initiated in June 1963 to determine if the environment within our lagoon laboratory and the lagoon itself was suitable for oyster culture. For 21 mo., we checked the growth (based on weight increases) and mortality of young oysters placed in the lagoon and also in the circulating water of the laboratory.

The procedures and results of the first year of the experiment were described in last fiscal year's report.[10] We mentioned that the initial mortality (August 1963) shown in figure 45 was probably caused by Gonyaulax monilata, and that examination of the dead oysters showed no evidence of the common oyster disease, Dermocystidium marinum. Mortality was nil during the subsequent 6 mo., but one lagoon oyster was lost. Then in March 1964, a lagoon oyster died. Two more died in May and two in June. All of these oysters were infected with D. marinum. No laboratory oysters died during this period. We hypothesized that the infection was picked up during the period of heavy feeding and rapid growth (September through November 1963). The laboratory oysters did not have a period of heavy feeding and rapid growth and, therefore, probably picked up less infection.

Laboratory oysters began dying from Dermocystidium infection in late summer of 1964. Three died in August, four in September, three in October, and one in December. The lagoon oysters continued to die throughout the summer of 1964: two died in July, two in August, three in September, and one in October. All were infected with Dermocystidium.

From July 1, 1964, to the end of the experiment on February 15, 1965, the lagoon and laboratory oysters grew at about the same rate. Growth was slow through the summer when the laboratory oysters gained about 0.3 g. (0.010 oz.) and those in the lagoon about 0.2 g. (0.007 oz.) per week. The growth of both groups increased as the hot weather ended. Through October, November, and December, the laboratory oysters gained 1.2 g. (0.042 oz.) per week compared to 1.1 g. (0.039 oz.) for those in the lagoon. Both groups had an average weight gain of 0.7 g. (0.025 oz.) per week from January 1, 1965, until the end of the experiment. On the basis of those living at the end of the experiment, the average monthly weight increases of lagoon and laboratory oysters were 5.1 g. (0.179 oz.) and 3.5 g. (0.123 oz.), respectively.

At the end of the experiment, the remaining oysters were examined for Dermocystidium. Among the four remaining laboratory oysters, infection ranged from light to heavy. Two of the lagoon oysters were uninfected, and infection levels in the other seven ranged from light to heavy.

Growth declined earlier among the laboratory oysters than among those in the lagoon. In their natural environment, small oysters are known to have a relatively high growth rate, which decreases as their size increases. We found that small oysters placed in the lagoon had a period of relatively rapid growth which began to taper off when they attained an underwater weight of about 70 g. (2.5 oz.). The growth rate of the laboratory oysters, however, decreased when they had reached about 29 g. (1 oz.). As a result, the laboratory oysters remained smaller than those in the lagoon.

Oysters that were uninfected with D. marinum became infected after being put into lagoon water, thereby showing that the disease existed in the lagoon. Mortality caused by D. marinum followed previously established patterns that show that oysters usually become infected during periods of heavy feeding and rapid growth in warm weather. If they are able to survive until the arrival of cooler weather, they will continue to survive at a reduced growth rate throughout the winter, then begin to die as warm weather approaches. Since the lagoon oysters took in more food, they also probably took in more D. marinum than those in the laboratory. This greater exposure apparently caused mortality to begin about 4 mo. earlier among lagoon oysters.

Oyster mortality in the lagoon is also caused by regularly occurring blooms of G. monilata. We suspected that deaths in August and September 1963 were caused by this organism. Its toxicity to oysters has since been demonstrated by another investigator. Undoubtedly, it contributes to the low population of naturally occurring oysters in the lagoon and would, therefore, make these waters unfit for long-term experiments. We thought that within the laboratory, the effects of G. monilata could be circumvented by placing experimental oysters in the laboratory's recirculating water tanks. This action, however, was not successful during the August 1963 bloom, possibly because the G. monilata were not detected in time. (See last year's report.)

This experiment has indicated that three factors affect the suitability of the lagoon water and the water within our laboratory for oyster experimentation. We have shown

[10] Circular No. 230, page 88, paragraph 1, line 3, should read: ". . . gaining 8.3 g. (.291 oz.) in September and 12.7 g. (0.445 oz.) in October.," and lines 6 and 7 should read: "Four oysters of this group died in May and June 1964."

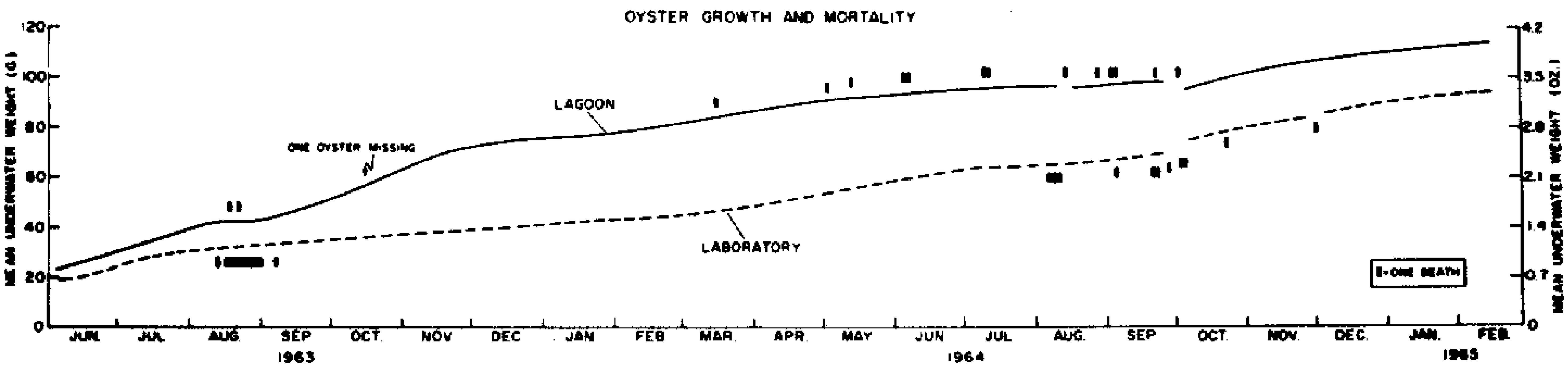


Figure 45.--Oyster growth and mortality, June 1963-February 1965.

that D. marinum is present in both locations. Also, growth within the laboratory is slower than that in the lagoon, and finally, as far as we know, a G. monilata bloom occurs every summer. We feel that the variation in growth rates between the two locations would not necessarily affect the suitability of the laboratory because many experiments are not concerned with rapid growth. G. monilata, as we have shown, can completely disrupt an experiment. Therefore, because of the regularity of blooms of this organism and also the presence of D. marinum, we conclude that the waters in the lagoon and in our laboratory are suitable only for short-term oyster experiments.

Raphael R. Proctor, Jr., Chemist

LIBRARY

The use of library services was greater during fiscal year 1965 than in previous years. Information and materials were supplied to the Laboratory staff, to individuals outside the Government, and to other libraries. The number of requests for interlibrary loans remained about the same as in the previous year. In addition to the processing of current acquisitions, more than half of the reclassification project was accomplished, and the subject index for recently acquired reprints was completed. The library participated in the 1965 edition of the Texas List of Scientific and Technical Serial Publications. The weekly list of library acquisitions was continued for distribution to the staff and to selected laboratories.

The demand for library materials by the Laboratory staff required certain changes in the loan regulations. A revised charging system and limitations on the loan period for selected groups of material were set up so that the publications would be more readily available to the entire staff.

In June 1965, the library facilities were made available to students attending the summer sessions of Texas A&M University at the A&M Marine Laboratory, Galveston, and we are providing instruction in the use of the library and reference service for about 30 students attending each 6-wk. session.

In October 1964, the librarian visited the other laboratory libraries of Region 2 to review their library classification systems as a part of a Regional management improvement project. At frequent intervals during the year, the librarian assisted the staff of the A&M Marine Laboratory in library procedures.

Stella Breedlove, Librarian

Table 11.--Number of publications in the library collection, 1964-65

Items	On hand 1964	Additions 1965	On hand 1965
Books...........	2,381	219	2,600
Journals (bound).......	519	64	583
Journals (unbound).....	1,395	195	1,590
Reprints........	2,948	304	3,252
Institutional...	9,344	1,936	11,280
Other...........	1,275	126	1,401
Total.......	17,862	2,844	20,706

MUSEUM

In August 1964, Building 305 was set aside as a scientific museum to maintain the valuable collections of biological specimens and statistical material in systematic order and to provide educational displays for the numerous school children, students, and teachers who visit the Laboratory each year. Laboratory furniture, including sink, was installed in the preparation room of the museum. Sea water, distilled water, and compressed air were piped in. Shelves were built in one of the wings for fish, plankton, microslide, shrimp, and estuarine collections. Another wing has about 300 cu. ft. of IBM cards, containing shrimp-landing statistics, that will be transferred eventually to magnetic tape to make room for storage.

Six display cases (each with six adjustable shelves) were received in April 1965. In this display section, 84 species of fish are now on exhibit; each case shows the types of fish caught at different depths.

The estuarine section displays specimens (crustaceans, fish, mollusks, and coastal plants) from the bays and estuaries and growth series of the southern quahog, scallop, and dosinia.

In the fish reference collection, 47 families comprising several specimens of 142 different species are arranged in phylogenetic order. All have been cataloged, showing the number of specimens in each jar, the cruise data, and time and place of capture.

About 7,000 plankton samples are stored in chronological order, and are in the process of being cataloged.

About 3,000 slides containing ovarian sections of penaeid shrimp have been stored and are also being cataloged.

About 2,500 shrimp and 5,000 estuarine specimens are stored in the museum.

The shell collection consists of mollusks from the Gulf of Mexico area, principally from the vicinity of Galveston. Forty-seven families are represented, comprising several specimens of 83 different species. These specimens are in phylogenetic order by families and are cataloged. Each specimen is labeled with scientific name, common name, range, date, and location; collector, catalog

Figure 46.--Shell display section in museum.

number, and number of specimens are recorded for individual collections.

The herbarium collection consists of mountings and preserved specimens of coastal and marine plants in phylogenetic order by families. Sixteen families and 33 different species are represented. Each specimen is cataloged and identified like those in the shell collection.

Live marine animals of the Gulf of Mexico are displayed in one section. Wood isopods, sea horses, pipefish, lined sole, flounder, crabs, sea anemones, rock shell snails, bryozoa, and several types of algae are now being shown.

Experiments on the retention of color in animals and plants have been made in the museum. Fish have kept their yellow, red, and black pigments. The saltwort has retained its green color even upon transfer from color retentive to 2 percent formaldehyde. Sea lavendar has kept its red and green colors. Work is being done in an effort to retain other colors for other fauna and flora.

A register has been provided for signatures of students, scientists, and others viewing the exhibits.

Laura M. Hermann, Museum Technician

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